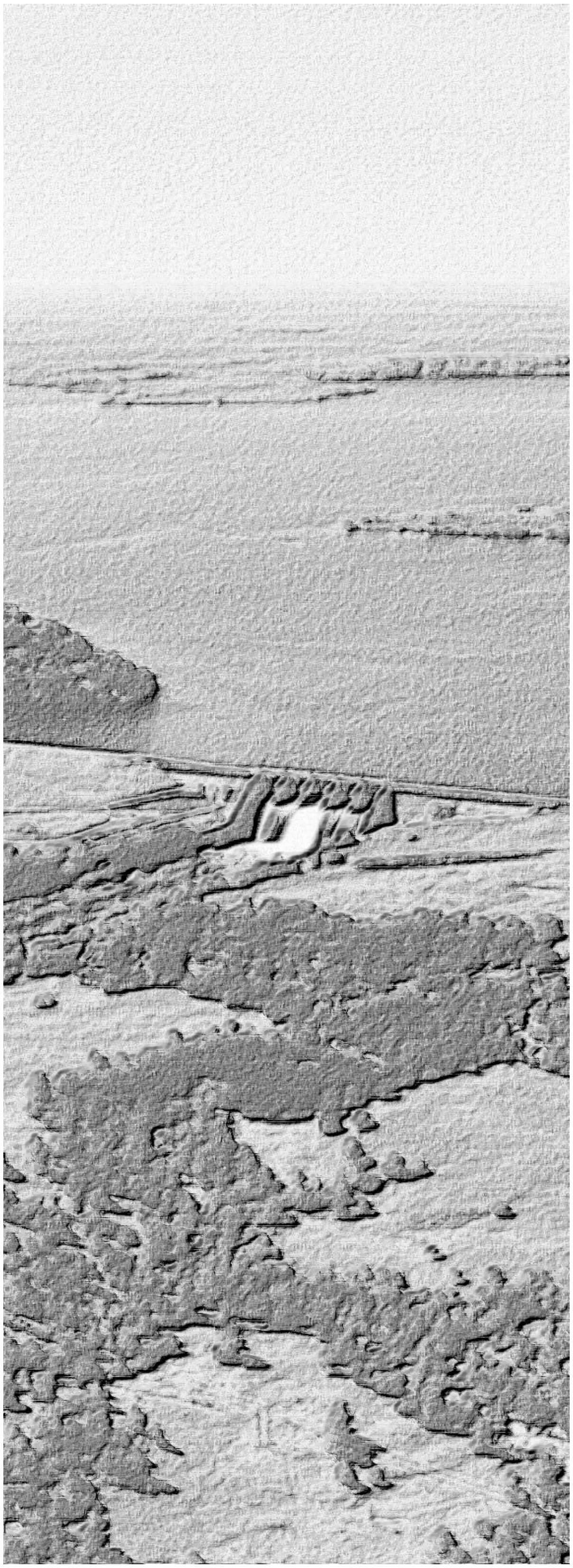


# CHAPTER THREE *Affected Environment*

**This chapter describes environmental factors of the Angostura Reservoir area that could be affected by the** alternatives detailed in Chapter Two. These factors are:

- Surface Water Quantity
- Surface Water Quality
- Groundwater
- Sediment
- Stream Corridor
- Wetlands
- Fisheries
- Wildlife
- Threatened or Endangered Fish and Wildlife Species/Species of Special Concern
- Social and Economic Conditions
- Indian Trust Assets
- Environmental Justice
- Cultural Resources
- Paleontological Resources.

Impacts are analyzed in Chapter Four and summarized in Table S.1 in the Summary.

To make it more understandable, some of the technical information in Chapters Three and Four has been summarized from appendix data (see Contents for a list of appendixes). Readers wanting more information should consult the appendixes on the CD in the back of the EIS. (Printed copies are available on request.)

## SURFACE WATER QUANTITY

Water available for future use was a concern of the public, and analyses of other environmental factors depended on the findings of this section. Measurements chosen to indicate changes (called *indicators*) were EOM (end-of-month) reservoir contents and elevations, releases from the reservoir to the District, releases to the river, and accretion and return flows.

The Cheyenne River, fed by runoff from rainstorms and the melting of snow in the spring, provides most of the water flowing into Angostura Reservoir (or inflows). The reservoir is the only large dependable source of surface water in the area (a description of the river can be found in Chapter One, "Background").

For purposes of this EIS, effects were considered from the reservoir downstream to where the Belle Fourche River joins the Cheyenne River (fig 3.1). Belle Fourche flows are large enough to mask water-quantity effects beyond this confluence. Water available in the reservoir was predicted by the AGRAOP computer model, using inflows into Angostura (including an evaporation allowance) for 1953-1997 to project water available for 1998-2042. (AGRAOP is detailed in Appendix A.) The model projected reservoir storage, ranging from a minimum elevation of 3163 feet (top of the inactive pool and the level of the District's canal inlet) to the top of the conservation pool at elevation 3187.2 feet. The 1981 area-capacity relationship was applied to Reclamation's DISSED computer model to predict future sedimentation in the reservoir.

### Cheyenne River

Information on flows was gathered from USGS (U.S. Geological Survey) at two gauging stations on the Cheyenne River and three tributaries above Angostura Reservoir, and at eight gauging stations on the main stem of the river and its tributaries below Angostura Dam. (The USGS also operates gauges on Cheyenne River tributaries further downstream between the Pine Ridge and Cheyenne River Reservations, but these are not affected by the Angostura Unit.)

Gauging locations are shown on fig. 3.1. Period of record for each gauge, drainage area, average annual and median (50% chance of occurring) flows, highest and lowest annual average flows, annual average runoff, and instantaneous peak flows (some outside the period of record) are recorded in Table 3.1 (Reclamation's HYDROMET [Hydrological Meteorologic database] estimated inflows/outflows and adjusted inflows for the reservoir are included in the table; Appendix B contains net computed inflows by month).

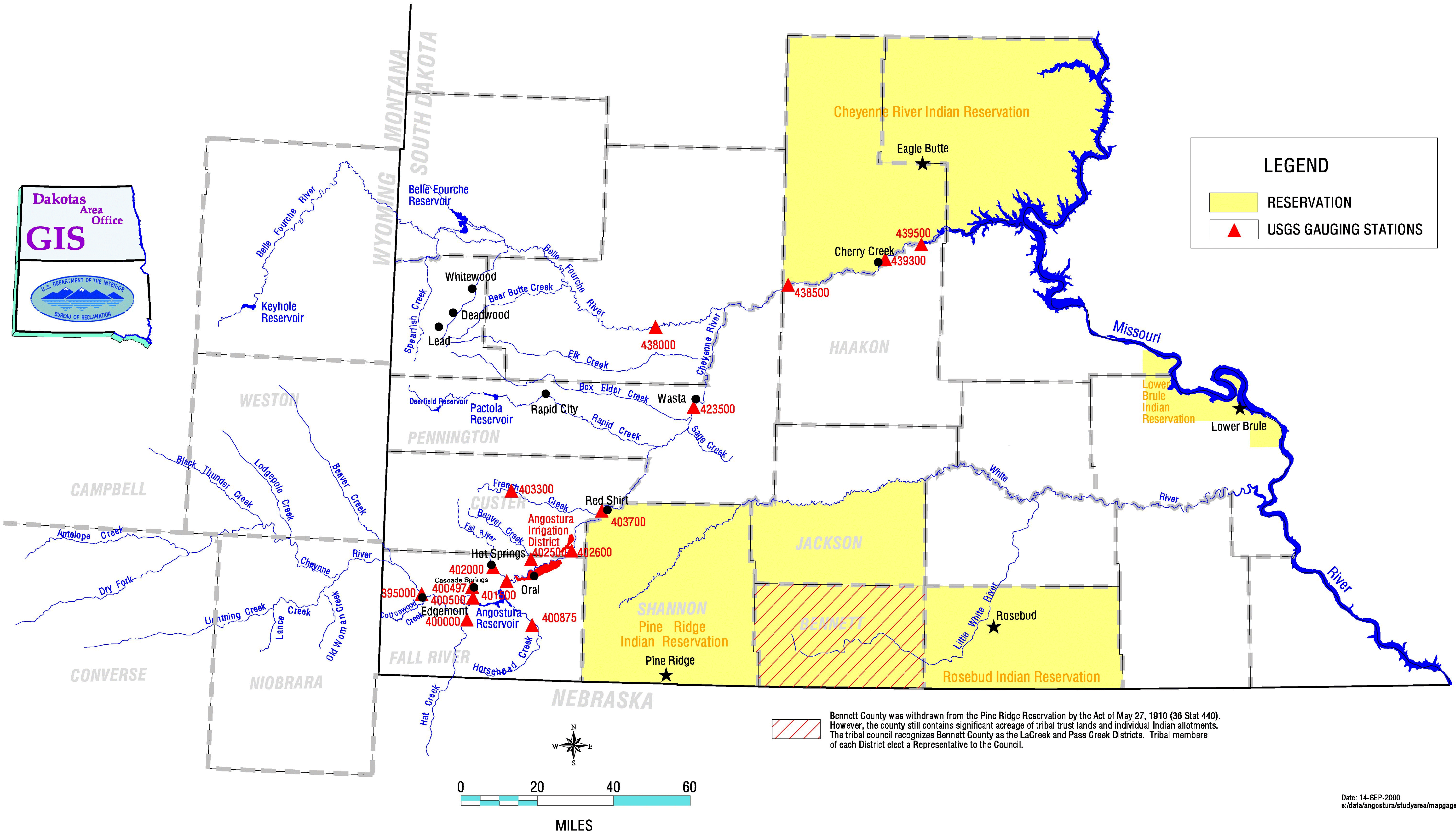
Diversions above Angostura Dam affect flows. Many stock and irrigation reservoirs above the Edgemont gauge store about 45,000 AF (acre-feet) of water (U.S. Geological Survey 1998.) Lander Ditch diverts water above the Hat Creek gauge to irrigate hayfields, and diversions upstream of the Horsehead Creek gauge irrigate about 640 acres in the vicinity. Flows are also diverted on the Cheyenne below the dam and on the tributaries of the river. Fall River flows have been regulated by Coldbrook Reservoir since 1952 and Cottonwood Springs Lake since 1969. Diversions also occur above the Beaver Creek gauge 25 miles below the dam (U.S. Geological Survey 1998). Stockade Reservoir regulates flow on French Creek 12 miles upstream of the gauge.

### Reservoir Inflows

Inflows were calibrated using AGRAOP by comparing historic EOM contents corrected for July 1958, and adjusted for the October 1966, and September 1981, area-capacity tables. Estimated adjusted inflows for 1953-1997

Fig. 3.1

# USGS GAUGING STATIONS



## Table 3.1: Gauges Supplying Data for the EIS

| Gauge | Station ID | Period of Record (Water Years) | Drainage Area (sq. mi.) | Annual Avg. Flows (cfs) | Median Flows (cfs) | Highest Annual Avg. Flows | | Lowest Annual Avg. Flows | | Annual Avg. Runoff (AF) | Instan-taneous Peak Flows (cfs) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | (cfs) | (yr.) | (cfs) | (yr.) | | |
| Cheyenne River At Edgemont | 06395000 | 1929-32 & 1947-97 | 7,143 | 81.4 | 10 | 434 | 1962 | 12.0 | 1988 | 58,990 | 28,000 |
| Hat Creek Near Edgemont | 06400000 | 1906 & 1951-97 | 1,044 | 16.9 | 0.4 | 112 | 1967 | 0.16 | 1989 | 12,230 | 13,300 |
| Cascade Springs Near Hot Springs | 06400497 | 1977 -95 Discontinued | 0.47 | 19.5 | 19 | 21.4 | 1984 | 16.3 | 1993 | 14,150 | 49 |
| Cheyenne River near Hot Springs | 06400500 | 1915-20 & 1943-72 | 8,710 | 139.9 | -- | 453 | 1962 | 30.9 | 1961 | 101,400 | 114,000 |
| Horsehead Creek At Oelrichs | 06400875 | 1984-1997 | 187 | 7.21 | 0.0 | 29.3 | 1986 | 0.0 | 1990 | 5,220 | 8,270 |
| Angostura Reservoir Adjusted Inflow | Adjusted | 1951-97 | 9,100 | 123.6 | -- | 565 | 1962 | 26.2 | 1961 | 89,500 | N/A |
| Cheyenne River below Angostura | HYDRO MET Data | 1953-97 | 9,100 | 59.9 | -- | 404 | 1962 | 0.0 | ---- | 43,400 | N/A |
| Cheyenne River below Angostura | 06401500 | 1951-78; partial year since 1978 | 9,100 | 67.1 | 1.4 | 404 | 1962 | 0.83 | 1961 | 48630 | 30,300 |
| Fall River at Hot Springs | 06402000 | 1970-97 | 137 | 21.9 | 22 | 25.5 | 1997 | 20.9 | 1981 | 15,880 | 13,100 |
| Beaver Creek near Buffalo Gap | 06402500 | 1939-97 | 130 | 7.19 | -- | 12.5 | 1995 | 3.78 | 1961 | 5,210 | 11,700 |
| Cheyenne River near Buffalo Gap | 06402600 | 1969-80 Discontinued | 9,800 | 107.4 | -- | 263 | 1971 | 56.5 | 1976 | 77,900 | 25,000 |
| French Creek above Fairburn | 06403300 | 1983-97 | 105 | 10.4 | 3.7 | 34.7 | 1995 | 1.01 | 1989 | 7,510 | 1,060 |
| Cheyenne River at Red Shirt | 06403700 | 1999 | 11,200 | 395 | 204 | N/A | N/A | N/A | N/A | 285,800 | 5,610 |
| Belle Fourche River near Elm Springs | 06438000 | 1954-97 | 7,210 | 1,036 | 100 | 1,036 | 1996 | 28.4 | 1961 | 250,400 | 14,100 |
| Cheyenne River near Wasta | 06423500 | 1964-97 | 12,800 | 340 | 123 | 1,143 | 1997 | 81.0 | 1989 | 246,200 | 26,900 |
| Cheyenne River near Plainview | 06438500 | 1951-81 & 1995-97 | 21,640 | 722 | 260 | 2,417 | 1997 | 97.2 | 1961 | 522,900 | 69,700 |
| Cheyenne River near Cherry Creek | 06439300 | 1961-94 Discontinued | 23,900 | 802 | 261 | 1,748 | 1978 | 100 | 1961 | 581,000 | 55,900 |
| Cheyenne River near Eagle Butte | 06439500 | 1934-67 Discontinued | 24,500 | 924 | N/A | N/A | N/A | N/A | N/A | 668,900 | 104,000 |

Sources: USGS *Water-Data Reports* SD-72-1, SD-80-1, SD-94-1, SD-97-1;
HYDROMET Data

**Table 3.2: Estimated Monthly Net Inflows, 1953-1997** (cfs)

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Avg. | 31.7 | 83.1 | 195.8 | 125.0 | 326.4 | 360.7 | 157.6 | 83.9 | 34.3 | 26.1 | 29.3 | 27.4 | 123.5 |
| Min. | 15.8 | 16.2 | 29.3 | 11.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 5.0 | 9.8 | 26.1 |
| 10-percentile | 18.9 | 27.0 | 51.7 | 27.6 | 23.4 | 10.1 | 12.0 | 8.1 | 0.0 | 7.2 | 16.5 | 16.9 | 38.0 |
| Median | 26.2 | 45.0 | 128.5 | 87.4 | 102.5 | 127.7 | 55.3 | 39.0 | 18.5 | 22.8 | 26.9 | 26.0 | 92.1 |
| 90-percentile | 44.0 | 151.3 | 417.3 | 270.9 | 1035.7 | 874.2 | 312.6 | 230.6 | 100.2 | 49.4 | 46.4 | 38.4 | 252.1 |
| Max. | 145.4 | 696.8 | 800.2 | 847.0 | 2535.5 | 2831.7 | 1369.4 | 450.5 | 275.6 | 217.9 | 53.8 | 68.3 | 562.7 |

Source: HYDROMET database adjusted for evaporation and precipitation by the AGRAOP model.

averaged 89,500 AF (123.5 cubic feet/second, or cfs), with an annual maximum of 409,000 AF (562.7 cfs) in 1962, an annual minimum of 19,000 AF (26.1 cfs) in 1961. Annual median inflows were 66,900 AF/year (92.1 cfs), about 75% of the annual average. Table 3.2 shows the monthly/annual inflow statistics for the 45 year period of record, including average, minimum, maximum, and 10-, 50- (median), and 90-percentile frequency of occurrence (10-percentile, as an example, means 10% of recorded values are equal to or less than the values in the table). Appendix C contains adjusted inflows into the reservoir, including a graphic depiction.

Gauges upstream of the reservoir (Cheyenne River at Edgemont, Hat Creek near Edgemont, Cascade Springs near Hot Springs, and Horsehead Creek at Oelrichs) showed average inflow to be about 90,000 AF/year (124.3 cfs). This is a close approximation of adjusted computed reservoir inflows based on actual elevations and measured releases of 89,500 AF/year. Under normal conditions, 60-80% of the runoff occurs during late spring and summer. A 1953-1997 period of record was retrieved from HYDROMET databases to compute monthly inflows for the reservoir, incorporating evaporation and precipitation. Net inflows were computed to average 82,520 AF/year (114 cfs), which took into account an average of 10 cfs evaporation from the reservoir.

### Reservoir Storage

Storage at Angostura has decreased from the natural build-up of sediment. Sediment surveys were done in 1965 and 1979, from which area-capacity tables were developed. The latest area-capacity table (done in 1981) shows an active conservation capacity of 82,443 AF between minimum elevation 3163.0 feet and maximum elevation 3187.2 feet, with a total capacity of 130,768 AF (Table 3.3 and fig. 3.2). About 29,000 AF of storage have been lost since construction of the dam (Table 3.3). Inactive storage is 39,700 AF between elevations 3139.75 feet (invert of the lowest river outlet) and 3163.0 feet. Dead storage below elevation 3139.75 feet is 8,598 AF. Surcharge capacity is 56,360 AF between elevations 3187.2 feet and 3198.1 feet, the maximum water surface. (Appendix D shows reservoir capacity allocations, Appendix E area capacity tables and curves.)

Tables 3.4 and 3.5 show monthly reservoir EOM contents and corresponding elevations, respectively, for 1953-1997. Content was obtained from HYDROMET water year database and then converted to a calendar-year database. The average EOM content was 112,100 AF at elevation 3179.83 feet, with the highest annual average storage 147,600 AF occurring in 1963, the lowest annual average of 67,900 AF in 1989. The maximum monthly

## Table 3.3: 1949, 1966, and 1981 Area-Capacity/Allocation Table

| | Elev. (ft) | 1949 Original | | | Oct. 1966 | | | Sept. 1981 | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Capacity Allocation | Capacity (AF) | Area (Acres) | Capacity Allocation | Capacity (AF) | Area (Acres) | Capacity Allocation | Capacity (AF) | Area (Acres) |
| Streambed at dam axis | 3062.0 | | 0.0 | 0.0 | | 0.0 | 0.0 | | 0.0 | 0.0 |
| | 3070.0 | | 16.0 | 42.0 | | 0.0 | 0.0 | | 0.0 | 0.0 |
| | 3075.0 | | 142.0 | 18.0 | | 0.0 | 0.0 | | 0.0 | 0.0 |
| | 3080.0 | | 230.0 | 22.0 | | 0.0 | 0.0 | | 0.0 | 0.0 |
| | 3090.0 | | 659.0 | 77.0 | | 0.0 | 0.0 | | 0.0 | 0.0 |
| | 3100.0 | | 1,723.0 | 152.0 | | 0.0 | 0.0 | | 0.0 | 0.0 |
| | 3110.0 | | 3,725.0 | 266.0 | | 0.0 | 0.0 | | 0.0 | 0.0 |
| | 3115.0 | | 5,236.0 | 340.0 | | 12.0 | 4.0 | | 0.0 | 0.0 |
| | 3120.0 | | 7,167.0 | 441.0 | | 39.0 | 30.0 | | 7.0 | 3.0 |
| | 3125.0 | | 9,825.0 | 630.0 | | 488.0 | 110.0 | | 187.0 | 69.0 |
| | 3130.0 | | 13,482.0 | 835.0 | | 2,253.0 | 610.0 | | 1,047.0 | 275.0 |
| | 3135.0 | | 18,235.0 | 1,065.0 | | 6,275.1 | 980.0 | | 3,957.0 | 889.0 |
| Top of Dead/ River outlet invert | 3139.75 | 23,740.3 | 23,740.3 | 1,250.3 | 11,223.6 | 11,223.6 | 1,094.0 | 8,598.0 | 8,598.0 | 1,064.8 |
| | 3140.0 | | 24,030.0 | 1,260.0 | | 11,484.0 | 1,100.0 | | 8,865.0 | 1,074.0 |
| | 3145.0 | | 31,118.0 | 1,580.0 | | 17,640.0 | 1,380.0 | | 14,737.0 | 1,275.0 |
| | 3150.0 | | 39,669.0 | 1,840.0 | | 25,310.0 | 1,700.0 | | 21,717.0 | 1,517.0 |
| | 3155.0 | | 49,677.0 | 2,170.0 | | 34,672.0 | 2,000.0 | | 30,505.0 | 1,998.0 |
| Top of spillway crest | 3157.2 | | 54,835.6 | 2,324.0 | | 39,406.0 | 2,154.0 | | 35,041.0 | 2,125.6 |
| | 3160.0 | | 61,401.0 | 2,520.0 | | 45,431.0 | 2,350.0 | | 41,220.0 | 2,288.0 |
| Top of inactive/ Canal outlet | 3163.0 | 45,727.2 | 69,467.4 | 2,724.0 | 41,607.8 | 52,831.4 | 2,500.0 | 39,727.0 | 48,325.0 | 2,448.8 |
| | 3165.0 | | 74,845.0 | 2,860.0 | | 57,765.0 | 2,600.0 | | 53,330.0 | 2,556.0 |
| Minimum recreation pool | 3170.0 | 20,614.6 | 90,082.0 | 3,245.0 | 19,477.6 | 72,309.0 | 3,170.0 | 18,625.0 | 66,950.0 | 2,892.0 |
| | 3175.0 | | 107,474.0 | 3,720.0 | | 88,718.0 | 3,450.0 | | 82,472.0 | 3,317.0 |
| | 3180.0 | | 127,307.0 | 4,210.0 | | 107,552.0 | 4,050.0 | | 100,417.0 | 3,861.0 |
| | 3185.0 | | 149,471.0 | 4,650.0 | | 128,563.0 | 4,420.0 | | 120,920.0 | 4,340.0 |
| Top of active conservation/ Top of spillway gates | 3187.2 | 90,451.6 | 159,919.0 | 4,841.0 | 85,928.6 | 138,760.0 | 4,706.0 | 82,443.0 | 130,768.0 | 4,612.0 |
| | 3190.0 | | 174,050.0 | 5,080.0 | | 152,478.0 | 5,080.0 | | 144,167.0 | 4,959.0 |
| | 3195.0 | | 200,470.0 | 5,490.0 | | 178,888.0 | 5,490.0 | | 170,107.0 | 5,417.0 |
| Top of surcharge/ Max. water surface | 3198.1 | 56,300.0 | 216,219.0 | 5,564.0 | 56,300.0 | 195,060.0 | 5,564.0 | 56,360.0 | 187,128.0 | 5,564.0 |

Source: 1949 original area-capacity table and 1966 and 1981 area-capacity tables computed from sediment resurvey of 1965 and 1979.

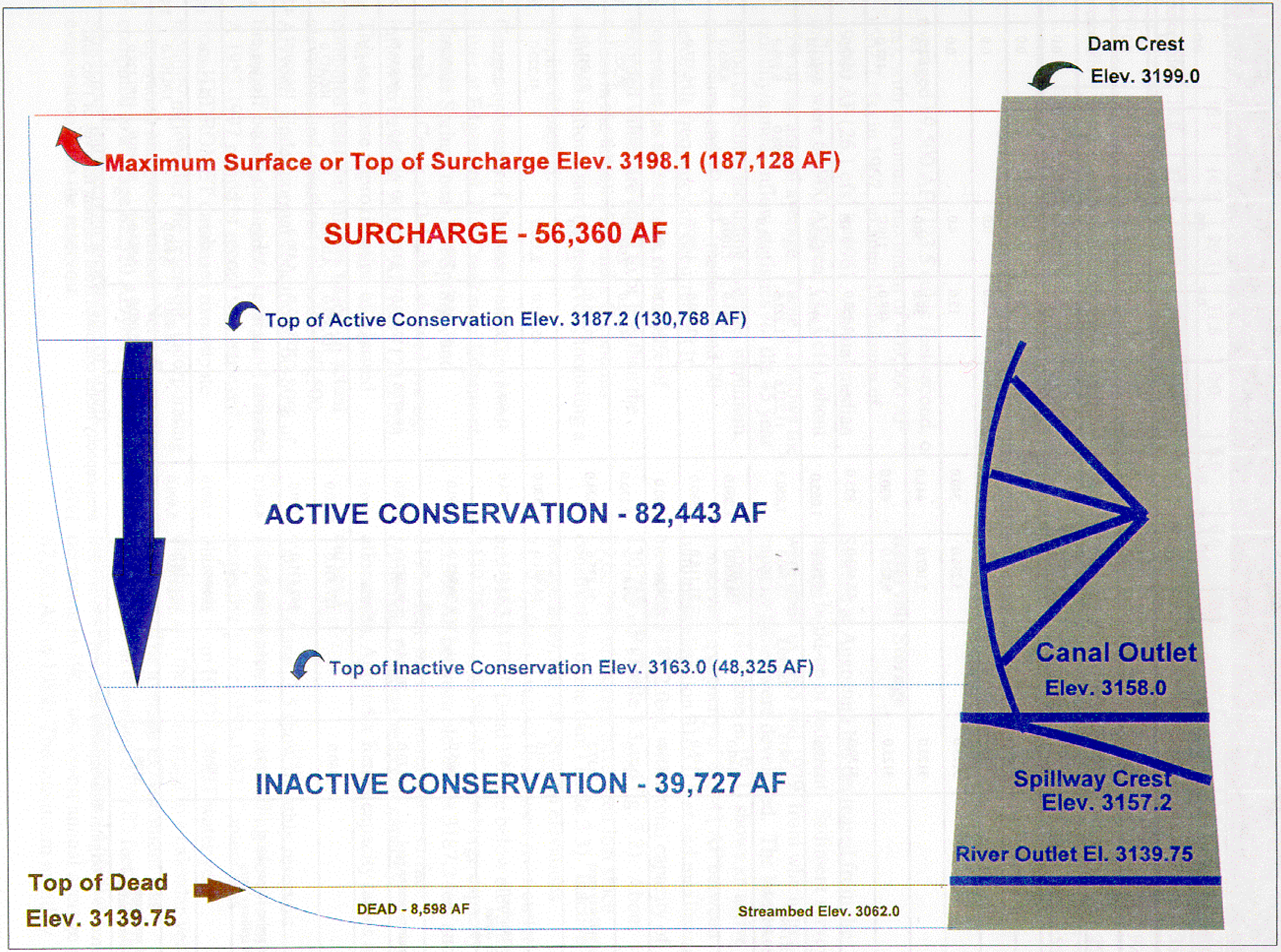



Fig.3.2: Elevations in the Reservoir

**Table 3.4: Monthly Reservoir EOM Contents, 1953-1997** (1,000 AF)

| | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. | Ann. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Avg. | 105.9 | 109.4 | 117.4 | 121.7 | 126.6 | 126.1 | 117.4 | 107.3 | 102.4 | 102.4 | 103.5 | 104.6 | 112.1 |
| Min. | 65.7 | 67.8 | 70.6 | 72.1 | 77.5 | 73.5 | 65.9 | 56.9 | 60.4 | 61.2 | 62.8 | 64.3 | 67.9 |
| 10-percentile | 74.0 | 80.9 | 87.9 | 89.1 | 100.2 | 95.8 | 82.5 | 71.9 | 70.0 | 70.6 | 71.5 | 72.7 | 85.4 |
| Median | 102.6 | 109.0 | 120.3 | 129.6 | 130.0 | 129.5 | 117.8 | 106.9 | 99.6 | 100.7 | 102.6 | 101.5 | 113.0 |
| 90-percentile | 132.2 | 137.1 | 138.4 | 142.1 | 157.9 | 158.9 | 147.7 | 142.0 | 135.1 | 129.6 | 129.9 | 129.9 | 134.5 |
| Max. | 148.1 | 153.2 | 160.0 | 160.3 | 162.2 | 160.2 | 160.2 | 155.7 | 160.0 | 155.5 | 150.7 | 149.6 | 147.6 |

Source: HYDROMET data—see Appendix F.

**Table 3.5: Monthly Reservoir EOM Elevations, 1953-1997** (ft.)

| | Jan | Feb | Mar | Apr | May | June | July | Aug | Sept | Oct | Nov | Dec | Ann |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Avg. | 3178.3 | 3179.2 | 3181.2 | 3182.2 | 3183.4 | 3183.3 | 3181.2 | 3178.6 | 3177.3 | 3177.5 | 3177.8 | 3178.1 | 3179.8 |
| Min. | 3164.4 | 3164.9 | 3165.5 | 3165.8 | 3166.1 | 3166.3 | 3164.7 | 3163.6 | 3162.9 | 3163.1 | 3163.4 | 3163.9 | 3164.8 |
| 10-percentile | 3170.1 | 3170.7 | 3172.7 | 3173.5 | 3177.0 | 3177.1 | 3174.1 | 3170.2 | 3168.5 | 3168.7 | 3169.1 | 3169.6 | 3173.9 |
| Median | 3179.3 | 3179.8 | 3182.5 | 3184.2 | 3186.0 | 3186.1 | 3183.8 | 3179.9 | 3178.3 | 3178.5 | 3178.9 | 3179.4 | 3181.7 |
| 90-percentile | 3185.4 | 3186.7 | 3187.0 | 3187.1 | 3187.2 | 3187.2 | 3186.7 | 3185.5 | 3184.0 | 3184.4 | 3184.7 | 3185.0 | 3184.3 |
| Max. | 3185.8 | 3187.0 | 3187.2 | 3187.2 | 3187.6 | 3187.3 | 3187.2 | 3186.3 | 3187.2 | 3186.2 | 3185.4 | 3185.3 | 3185.7 |

Source: HYDROMET data—see Appendix F.

EOM content of 162,200 AF at elevation 3187.6 feet occurred in May 1962, the minimum of 56,900 AF in August, 1989. The monthly minimum EOM elevation of 3162.92 feet occurred September 1960. (Appendix F contains the HYDROMET database and AGRAOP EOM contents and elevations based on adjusted inflows.)

### Reservoir Releases to the District

The District's water demands depend on the acres irrigated and the CIR (crop irrigation requirement). CIR was estimated to be 18.74 inches/acre based on the Modified Blaney-Criddle Method. District records for 1993 show a cropping pattern of 50% alfalfa, 38% corn, 8% pasture, 3% grain, and 1% beans; this pattern was used in the analysis.

Table 3.6 shows monthly releases to the District based on HYDROMET data, including District records from 1955 (when they began irrigating) -1997, showing an annual average release to the main canal of 40,400 AF/year (55.2 cfs) to irrigate 10,000 acres. Droughts, lack of carry-over storage, and unirrigated lands (such as lands in the Conservation Reserve Program)

**Table 3.6: Monthly Reservoir Releases to the District, 1955-1997** (cfs)

| | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov | Dec. | Ann. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Avg. | 0.0 | 0.0 | 0.0 | 4.5 | 53.6 | 74.5 | 208.0 | 213.4 | 97.9 | 10.0 | 0.0 | 0.0 | 55.2 |
| Min. | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 3.4 | 112.2 | 68.3 | 0.0 | 0.0 | 0.0 | 0.0 | 16.4 |
| 10-percentile | 0.0 | 0.0 | 0.0 | 0.0 | 2.0 | 21.8 | 134.0 | 156.1 | 52.4 | 0.0 | 0.0 | 0.0 | 43.0 |
| Median | 0.0 | 0.0 | 0.0 | 0.0 | 53.7 | 62.2 | 221.2 | 222.8 | 97.5 | 0.0 | 0.0 | 0.0 | 55.6 |
| 90-percentile | 0.0 | 0.0 | 0.0 | 15.1 | 93.7 | 135.5 | 262.2 | 267.4 | 139.2 | 33.5 | 0.0 | 0.0 | 66.1 |
| Max. | 0.0 | 0.0 | 0.0 | 45.4 | 117.1 | 218.5 | 287.9 | 299.2 | 191.6 | 65.1 | 1.7 | 0.0 | 81.0 |

Source: HYDROMET database–see Appendix G.

cause less than the 12,218 acres contracted-for to be irrigated. Annual median canal flows are 40,700 AF (55.6 cfs) at present, almost the same as the annual average. Maximum monthly releases of 18,400 AF (299.2 cfs) occurred in August 1959, the minimum of zero during some months in the normal irrigation season. The highest annual release of 59,100 AF (81.0 cfs) occurred in 1958, while the lowest of 12,100 AF (16.4 cfs) occurred in 1961, reflecting record minimal inflows of 19,000 AF(26.1cfs). (Appendix G gives canal releases by month.)

### Reservoir Releases to the River

Annual average river release is 59.9 cfs (43,400 AF), with the highest annual average of 406.7 cfs (294,500 AF total) occurring in 1962, the lowest annual average of zero in both 1976 and

**Table 3.7: Monthly Reservoir Releases to the River, 1953-1997**[1] (cfs)

| | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov | Dec. | Ann. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Avg. | 10.2 | 20.3 | 66.0 | 38.7 | 183.7 | 280.3 | 75.3 | 18.9 | 6.1 | 4.8 | 6.6 | 7.9 | 59.9 |
| Min. | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 10-percentile | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 |
| Median | 0.0 | 0.0 | 0.0 | 1.7 | 8.1 | 13.4 | 1.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 29.5 |
| 90-percentile | 47.5 | 76.0 | 160.4 | 123.0 | 527.9 | 803.6 | 192.6 | 52.3 | 8.4 | 12.7 | 23.9 | 37.1 | 177.4 |
| Max. | 117.1 | 212.5 | 673.3 | 369.7 | 2384.2 | 2825.0 | 1229.5 | 198.4 | 95.8 | 58.5 | 89.1 | 84.6 | 406.7 |

Source: HYDROMET database—see Appendix G.

1977 (Table 3.7). Annual median flow is 29.5 cfs (20,600 AF), about half the annual average. USGS records (1998) show the highest daily average of 20,600 cfs occurred June 18, 1962, with an instantaneous peak flow of 30,300 cfs on May 20, 1978. Uncontrolled releases occur when reservoir capacity reaches elevation 3187.2 feet (the top of spillway gates). Seepage past the dam's radial gates is small, normally about 3.3 cfs (200 AF/month).

Estimated monthly river flows at the Buffalo Gap gauge 40 river miles downstream are shown in Table 3.8. They represent reservoir releases combined with accretion and return flows. Flows at Buffalo Gap are assumed to approximate flows at Red Shirt, about 10 river miles further downstream.

### Accretion and Return Flows

*Accretion flow*s join the river from tributaries, springs, and the District. Table 3.9 shows accretion flows from the reservoir downstream to the Buffalo Gap gauge, including Fall River and Beaver Creek inflows measured at the gauges and estimated inflows from ungauged areas based on measured flows at Hat Creek.

Table 3.9 also shows estimated average annual *return flows* from the District, the remaining irrigation water returning to the river after consumption by crops and recharge to groundwater. District return flows are estimated to be 54% of releases to the canal, or about 30 cfs. Estimated return flows of 2 cfs are included from irrigation along Beaver Creek. The only outflows in the table are for evapotranspiration from the stream corridor.

**Table 3.9: Accretion/Return Flows Between the Dam and the Buffalo Gap Gauge, 1955-1997**[1] (cfs)

| Sources | Flows (cfs) |
|---|---|
| Fall River | 23 |
| Beaver Creek | 7 |
| Beaver Creek Return Flows | 2 |
| Ungauged Flows | 8 |
| District Return Flows | 30 |
| Evapotranspiration from Stream Corridor | -4 |
| Total Accretions | 66 |

[1] Appendix J shows how accretion and return flows were calculated.

**Table 3.8: Estimated Monthly Flows at the Buffalo Gap Gauge, 1955-1997**[1] (cfs)

| | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. | Ann. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Avg. | 60.5 | 79.5 | 133.8 | 99.7 | 262.1 | 382.6 | 129.5 | 68.8 | 71.4 | 79.9 | 72.5 | 70.6 | 125.9 |
| Min. | 47.8 | 56.3 | 53.1 | 44.1 | 45.7 | 47.5 | 41.2 | 48.2 | 60.8 | 57.6 | 60.7 | 59.7 | 55.8 |
| 10-percentile | 50.7 | 58.1 | 56.9 | 48.9 | 48.0 | 50.5 | 45.3 | 50.3 | 63.7 | 61.6 | 62.9 | 60.8 | 57.5 |
| Median | 53.2 | 61.7 | 65.5 | 67.8 | 74.7 | 69.2 | 59.5 | 55.6 | 69.3 | 68.7 | 67.0 | 64.2 | 96.9 |
| 90-percentile | 76.9 | 120.7 | 227.1 | 192.7 | 733.2 | 945.8 | 238.3 | 77.6 | 74.8 | 89.4 | 98.5 | 88.4 | 256.2 |
| Max. | 145.5 | 283.9 | 736.6 | 433.9 | 2475.5 | 2950.8 | 1312.1 | 254.7 | 163.5 | 415.3 | 155.2 | 158.2 | 475.6 |

[1] Appendix J shows the water budget analysis done in cooperation with USGS.

## SURFACE WATER QUALITY

The public asked that possible contaminants from grazing, recreation, oil wells, the bombing range on the Pine Ridge Reservation, and mining be analyzed in this EIS, in sediment, aquatic life, and in the water itself. Reclamation added other water quality considerations to be examined in this section.

Information from many sources was used to characterize water quality. Two U.S. Department of the Interior studies describe water quality in the Cheyenne River basin. In 1988, the NIWQP (National Irrigation Water Quality Program) studied the Angostura Unit's effects on water quality and biota (Greene et al. 1990). Sampling included water and sediment samples from Angostura Reservoir. Since South Dakota was undergoing a drought in 1988, NIWQP did a Verification Study in 1994 on water quality aspects of the earlier study; it has not been published yet, but data were provided by USGS (Joyce Williamson, 1999: personal communication). The EPA (Environmental Protection Agency) collected data from the reservoir and river in 1974 as part of the NES (National Eutrophication Survey).

The SDDENR (South Dakota Department of Environment and Natural Resources) has sampled the reservoir each year since 1989 (except for 1990). Data collected included temperature, DO (dissolved oxygen) profiles, *Secchi* depths (a measurement of the depth to which a disk put into water can be seen), nutrient species, and total suspended solid concentrations from surface and bottom samples. The SDDENR published temperature and DO profiles measured from 1991-1994 (Stueven and Stewart 1996).

The OST (Oglala Sioux Tribe) monitored water quality of the Cheyenne River near Red Shirt from 1993-1997 (Hoof 1998). They supplied data to supplement NIWQP data. The CRST(Cheyenne River Sioux Tribe) sponsored a USGS study of water quality trends in the Cheyenne and Moreau Rivers (Heakin 1998). Water and fish were sampled in July and August 1997 (Plateau 1998). This information was provided for the EIS. The CRST have also undertaken a sediment monitoring study of the Cheyenne and Moreau rivers funded by EPA; contaminant data have been provided for the EIS.

Reclamation sampled the reservoir and the river for DO, TDS (total dissolved solids, or salts), major ions, trace elements, and pesticides in 1997 and 1998. Sites upstream of the reservoir were sampled as were sites down to Cherry Creek on the Cheyenne River Sioux Reservation. These samples included water, bed sediment, and fish.

### Angostura Reservoir

Reservoirs and lakes go through a natural aging process wherein they are transformed from a lake into a marsh, and then into a meadow. This gradual process can be accelerated by an increase of nutrients and sediments. When determining status of a reservoir, a set of trophic states are used:

- *oligotrophic* or low in nutrients
- *mesotrophic* or moderate in nutrients
- *eutrophic* or high in nutrients
- *hypereutrophic* or very high nutrients.

The *Clean Lakes Report* (South Dakota Department of Environment and Natural Resources 1996) categorized Angostura Reservoir as mesotrophic, with a declining trend in water quality: "Major pollution sources of the reservoir, however, were categorized as natural" (p.5). A trend line in that report based on the trophic state index for the last decade indicated a trend towards oligotrophy, or improving water quality.

One of the effects of eutropication is more algal growth which decreases water clarity, can cause odor and taste problems, and can increase toxicity to fish and invertebrates. Oxygen and carbon dioxide levels are also directly affected by plant activity, which, in turn, are related to health of aquatic species. Since most aquatic organisms require oxygen for survival, DO is often used to evaluate general health of reservoirs and streams. It can be depleted to the point where the bottom of a reservoir is completely without oxygen.

Most reservoirs are also subject to seasonal changes. Ice cover with a relatively constant temperature from surface to bottom is typical in winter. As temperatures rise in the spring, ice melts and the surface warms up. Even slight winds result in mixing of the water while the water temperature is uniform. A temperature gradient develops as summer progresses where the surface of the reservoir is much warmer than the bottom, and a thermocline exists where water changes dramatically from warm to cold. In the late summer, surface water begins to cool. It becomes more dense as a result and sinks towards the bottom of the reservoir. When water temperature becomes the same from top to bottom, the fall *turnover*, or complete mixing, takes place.

As mentioned before, Angostura Reservoir was surveyed for the NES in 1974; sampling was repeated in 1978 and again from 1989-1995 by SDDENR. Data from these studies show similar conditions: Elevated nitrogen, phosphorus, and chlorophyll, indicative of eutrophication of the reservoir. In late summer, DO was depressed at depth, but complete oxygen depletion did not occur. The reservoir was also relatively saline, or high in dissolved solids. It was well mixed (little or no difference in water temperature with depth) and DO was near saturation in April. The thermal stratification was well established by July, with the thermocline between 30-40 feet deep. DO decreased below that depth. In September, the cooling reservoir returned to a nearly fully mixed temperature profile, although there was lingering depression of DO.

Temperature and DO samples collected by SDDENR in the spring, summer, and fall in 1978, 1989-1990, and 1992-1995 indicated the reservoir tended to be stratified from June-August (fig. 3.3). The minimum bottom DO occurred in August, with measurements of less than 1 mg/L (milligram/liter). Fall turnover occurred during early to mid-September.

## Cheyenne River

### *Dissolved Oxygen*

DO in water is not constant, affected as it is by temperature, air pressure, and biology. A calculated DO concentration for a given temperature and barometric pressure is used with a measured DO concentration to produce a percent of saturation. This value can be used to evaluate stream health, since it takes into account both changes in temperature and air pressure.

EPA recommends 3 mg/L as the instantaneous minimum DO concentration for adult warmwater fish like those in the Cheyenne River. South Dakota has designated stream reaches for specific beneficial uses and has established standards necessary to support the uses. The Cheyenne River from the Wyoming border to Lake Oahe is designated by the State for *Warmwater Permanent* or *Warmwater Semi-permanent Fish Life Propagation* (depending on the section of river), *Immersion Recreation*, *Limited Contact Recreation*, *Wildlife Propagation and Stock Watering*, and *Irrigation Waters*. State standards specify DO should be greater than 5 mg/L to maintain designated uses.

The OST are reviewing streams—including the Cheyenne River where it borders the Reservation—to likewise determine beneficial uses and standards. Uses will probably parallel

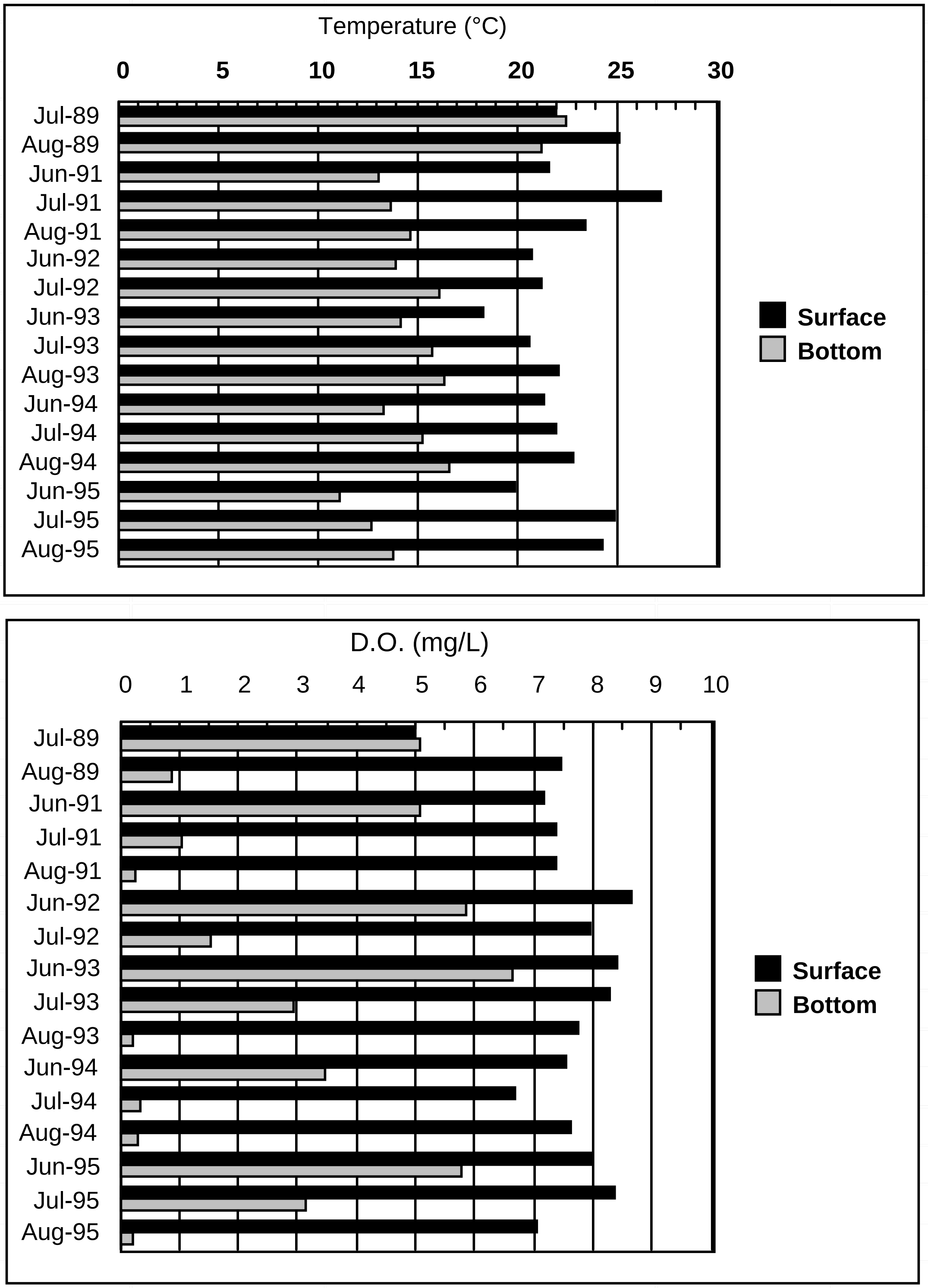



**Fig. 3.3: Reservoir Surface and Bottom Temperatures/DO, Summer 1989-1995**

those of the State, while standards will probably meet or exceed State standards (Kim Clausen, 2000: personal communication).

DO concentrations in the river and reservoir from NIWQP sampling, the OST study, and the CRST studies are listed in Table 3.10. Percent saturation was available for the Verification Study and the OST study, while it was estimated for NIWQP sampling and the CRST sediment monitoring study from temperatures and estimated barometric pressure of 680 mm (millimeters) of mercury.

Table 3.10 shows periodic low DO in the river: DO for December 1993 and May 1996, for example, was at 10% and 8% saturation, respectively. The December 1993 reading would correspond to about 1.5 mg/L DO, while that for May 1996 would correspond to about 0.8 mg/L. Other than these two readings, no DO concentrations were found to be less than 5 mg/L. There is no way to estimate frequency or duration of low DO episodes, however, from the limited data available.

### *Total Dissolved Solids*

Another simple and effective measure of water quality is specific *EC* (electrical conductance). EC measures the capacity of water to conduct electricity, and specific electrical conductivity is the conductance at a specific temperature of a 1-centimeter cross-sectional area (the standard temperature is 25º C, so field measurements are adjusted to account for temperature changes). Since EC measures the electricity conducted, it is generally proportional to concentrations of TDS in the water. Pure water is a very poor conductor; as dissolved solids increase, EC of the water increases.

TDS can be used to measure effects of irrigation on water quality. TDS in irrigation water, after plant consumption and evaporation, can become concentrated in return flows. The effects of irrigation thus can be measured by increases in TDS downstream of the irrigated area, or in return flows.

TDS, as mentioned before, is equivalent to salts found in water. Major ions that make up TDS include calcium, magnesium, sodium, potassium, sulfate, chloride, and bicarbonate. The water immediately above Angostura Reservoir is predominately a calcium-sulfate type, while downstream of the reservoir it becomes a calcium-sodium sulfate type.

Generally, calcium, sodium, and sulfate concentrations progressively increase from upstream to downstream. NIWQP data showed TDS concentrations decreased from upstream to immediately downstream of the reservoir, and then progressively increased thereafter. A salt budget on the Cheyenne River and tributaries, based on information from 1979-1980 (years with the most complete geographic information available), showed similar results (Table 3.11). TDS concentrations in return flows from the District were similar to concentrations measured upstream at the Edgemont gauge.

During low-flow years, upstream concentrations generally were higher, diluted by mixing in the reservoir, and then increasing again below the dam. When flows were normal-high in 1997, TDS concentrations generally were lower. Calcium concentrations increased from above the reservoir to near Custer County Bridge 656, then decreased again. Sodium in 1997 stayed relatively constant, and sulfate followed a pattern similar to sodium. The decrease in calcium and sulfate near the Custer County Bridge and Cherry Creek could be due to dilution from Beaver Creek, Cottonwood Creek, French Creek, Spring Creek, and Rapid Creek, tributaries to the river (see fig. 3.1).

## Table 3.10: DO/Saturation in the Cheyenne River

| Study | Site | Date | DO (mg/L) | Saturation (%) |
|---|---|---|---|---|
| NIWQP | River near Hot Springs | 5/4/88 | 7.6 | 96.2 |
| NIWQP | River near Hot Springs | 6/22/88 | 7.2 | 104.0 |
| NIWQP | River near Hot Springs | 8/22/88 | 7.9 | 108.0 |
| NIWQP | River near Hot Springs | 11/1/88 | 8.8 | 98.9 |
| NIWQP | Horsehead Creek at Oelrichs | 5/5/88 | 9.0 | 108.0 |
| NIWQP | Angostura Reservoir | 5/4/88 | 1.3 | 13.5 |
| NIWQP | Angostura Reservoir | 6/23/88 | 7.6 | 96.2 |
| NIWQP | Angostura Reservoir | 11/1/88 | 9.1 | 90.1 |
| NIWQP | Fall River at mouth | 5/5/88 | 9.9 | 118.0 |
| NIWQP | Fall River at mouth | 6/23/88 | 6.4 | 95.5 |
| NIWQP | Fall River at mouth | 8/24/88 | 8.4 | 112.0 |
| NIWQP | Fall River at mouth | 11/3/88 | 9.8 | 109.0 |
| NIWQP | River above Buffalo Gap | 5/3/88 | 9.8 | 110.0 |
| NIWQP | River above Buffalo Gap | 6/21/88 | 6.0 | 84.5 |
| NIWQP | River above Buffalo Gap | 8/23/88 | 7.9 | 94.0 |
| NIWQP | River above Buffalo Gap | 11/2/88 | 10.4 | 103.0 |
| NIWQP | Iron Draw near Buffalo Gap | 5/6/88 | 8.5 | 101.0 |
| NIWQP | Iron Draw near Buffalo Gap | 6/21/88 | 7.8 | 110.0 |
| NIWQP | Iron Draw near Buffalo Gap | 8/23/88 | 8.0 | 101.0 |
| NIWQP | Iron Draw near Buffalo Gap | 11/2/88 | 9.2 | 100.0 |
| NIWQP | Cottonwood Creek near Buffalo Gap | 5/3/88 | 10.1 | 107.0 |
| NIWQP | Cottonwood Creek near Buffalo Gap | 6/24/88 | 2.8 | 35.9 |

| Study | Site | Date | DO (mg/L) | Saturation (%) |
|---|---|---|---|---|
| NIWQP | Cottonwood Creek near Buffalo Gap | 8/24/88 | 3.1 | 34.8 |
| NIWQP | Cottonwood Creek near Buffalo Gap | 11/2/88 | 7.2 | 71.3 |
| NIWQP | River near Fairburn | 5/6/88 | 6.6 | 82.5 |
| NIWQP | River near Fairburn | 6/20/88 | 9.4 | 142.0 |
| NIWQP | River near Fairburn | 8/26/88 | 8.9 | 109.0 |
| NIWQP | River near Fairburn | 10/31/88 | 11.2 | 110.0 |
| Verification Study | River at Edgemont | 4/19/94 | 9.1 | 103.0 |
| Verification Study | River at Edgemont | 9/8/94 | 7.6 | 107.0 |
| Verification Study | River downstream of Dam | 4/19/94 | 11.8 | 120.0 |
| Verification Study | River downstream of Dam | 9/9/94 | 8.3 | 104.0 |
| Verification Study | River near Bridge 656 | 4/20/94 | 9.2 | 101.0 |
| Verification Study | River near Bridge 656 | 9/8/94 | 8.8 | 107.0 |
| Verification Study | River near Fairburn | 4/20/94 | 9.6 | 110.0 |
| Verification Study | River near Fairburn | 9/8/94 | 8.7 | 102.0 |
| OST | CRI | 12/12/93 | 1.5 | 10.1 |
| OST | CRI | 5/25/95 | | 87.1 |
| OST | CRI | 5/15/96 | 0.8 | 8.0 |
| OST | CRI | 9/30/96 | | 32.8 |
| OST | CRI | 7/1/97 | | 90.5 |
| OST | CRI | 10/16/97 | | 82.0 |
| OST | CRII | 7/16/97 | | 71.9 |
| OST | CRII | 10/1/97 | | 86.9 |
| CRST | CR1 | 7/28/97 - 8/3/97 | 9.0 | 114.0 |
| CRST | CR2 | 7/28/97 - 8/3/97 | 9.1 | 126.0 |
| CRST | CR3 | 7/28/97 - 8/3/97 | 11.8 | 157.0 |
| CRST | CR4 | 7/28/97 - 8/3/97 | 10.5 | 146.0 |

The OST sampled the river in May or June for five years when flows were high, and again in the fall or winter when flows were low. These samples showed concentrations changing, with lower concentrations during high flows and higher concentrations during low flows. This generally is what would be expected for most constituents due to dilution.

An analysis along the river's lower reach found upward trends in sulfate, chloride, and TDS over time (Heakin 1998). EPA's 250 mg/L SMCL (secondary maximum contaminant level) for sulfate was exceeded, as was the 500 mg/L level for TDS. It bears repeating that the Cheyenne River is not designated for human consumption, although it may be used for that purpose; drinking water standards are included in this section only as a means of comparison.

### *Trace Elements*

Trace or minor elements are solids dissolved (or held as very small particulates ) in water, generally at concentrations of less than 1 mg/L (Hem 1985). Although trace elements occur at low concentrations, they can significantly affect the aquatic environment and human health.

The NIWQP study found elevated trace elements in several Cheyenne River tributaries. Findings from the NIWQP study and the Verification Study—as well as the Reclamation and OST studies—are shown in Table 3.12. These findings are compared to South Dakota Aquatic Life standards, when available, or to South Dakota Human Health standards or EPA MCLs (maximum contaminant levels) or SMCLs otherwise.

MCLs are based on total recoverable concentrations, so comparisons in the table are conservative since total concentrations are greater than, or equal to, dissolved concentrations. Also, some of the aquatic life standards vary with water hardness: the findings in the table are based on 100 mg/L hardness as presented in the *State Water Quality Standards: Appendix B*. Water in the area is generally very hard, with concentrations from 500-1,800 mg/L. Higher standards are applied to hard water because aquatic organisms can tolerate higher levels of trace elements at a higher hardness.

The OST study found antimony concentrations ranging from 220-360 $\mu$g/L (micrograms/liter), which exceeded drinking water standards (Table 3.12). The 4 $\mu$g/L cadmium found at Fall River and the 5 $\mu$g/L cadmium at Cheyenne River above Buffalo Gap are below both aquatic life acute and chronic standards based on hardnesses of 560 and 780 mg/L, respectively, the day the samples were collected. Fall River was a background site in the NIQWP study, and the Cheyenne River site receives return flows. Neither antimony nor cadmium are characteristic of irrigation return flows.

A copper concentration of 11 $\mu$g/L collected at the District canal didn't exceed the aquatic chronic standard of 67 $\mu$g/L based on a hardness of 800 mg/L. Lead concentrations from the NIWQP study didn't exceed the hardness-adjusted standards of 22-17 $\mu$g/L. Reclamation's study also reported a lead concentration of 5 $\mu$g/L from the Cheyenne River at the Cherry Creek site. Lead is not associated with return flows.

A mercury concentration of 5.3 $\mu$g/L at Cheyenne River above Buffalo Gap exceeded the aquatic acute and chronic standards of 2.4 and 0.012 $\mu$g/L, respectively. This could be the result of sample contamination, however, or an error at the laboratory analyzing the samples (Greene et al. 1990).

Several selenium concentrations at Iron Draw near Buffalo Gap and Cottonwood Creek near Buffalo Gap exceeded the aquatic chronic standard of 5 $\mu$g/L. At the time of the NIWQP study, the chronic standard was 10 $\mu$g/L, and only the two Cottonwood Creek samples

## Table 3.11: Annual TDS Concentrations, Total Salt Loads and Flows (1979-1980)

| Site | Cheyenne River | | | Tributaries | | |
|---|---|---|---|---|---|---|
| | 1979 | | | 1979 | | |
| | TDS (mg/L) | Flows (AF) | Load (tons) | TDS (mg/L) | Flows (AF) | Load (tons) |
| Cheyenne at Edgemont | 2,300 | 61,100 | 134,420 | | | |
| Cheyenne at Dam | 1,705 | 20,000 | 44,380 | | | |
| Fall River | | | | 962 | 16,000 | 21,160 |
| Beaver Creek | | | | 2,041 | 5,700 | 15,550 |
| Cheyenne at Buffalo Gap | 1,973 | 66,368 | 170,850 | | | |
| Rapid Creek | | | | 604 | 33,300 | 27,400 |
| Cheyenne at Wasta | 1,396 | 168,500 | 292,190 | | | |
| Belle Fourche River | | | | 1,945 | 160,200 | 319,400 |
| Cheyenne at Plainview | 1,436 | 322,700 | 588,520 | | | |
| Cheyenne at Cherry Creek | 1,782 | 350,400 | 731,980 | | | |
| | 1980 | | | 1980 | | |
| Cheyenne at Edgemont | 2,996 | 32,800 | 119,850 | | | |
| Cheyenne at Dam | 1,767 | 17,900 | 45,870 | | | |
| Fall River | | | | 1,025 | 15,400 | 21,690 |
| Beaver Creek | | | | 2,165 | 4,300 | 12,030 |
| Cheyenne at Buffalo Gap | 2,124 | 55,171 | 160,280 | | | |
| Rapid Creek | | | | 646 | 28,500 | 24,380 |
| Cheyenne at Wasta | 1,500 | 96,500 | 196,450 | | | |
| Belle Fourche River | | | | 2,085 | 79,000 | 193,830 |
| Cheyenne at Plainview | 1,599 | 174,000 | 358,080 | | | |
| Cheyenne at Cherry Creek | 1,883 | 184,000 | 428,260 | | | |

## Table 3.12: Dissolved Trace Elements in the River Near the District ($\mu$g/L)

| | Criteria | Standard | NIWQP | Verification | Reclamation | OST |
|---|---|---|---|---|---|---|
| Aluminum | EPA SMCL | 50-200 $\mu$g/L | | | | <100 - 100 |
| Antimony | SD Human Health | 4,300 $\mu$g/L[1] | | | | 220 -360 |
| Arsenic | SD Human Health | 0.14 $\mu$g/L[1] | <1 - 4 | <1 - 2 | <1 - 6 | <100 - 100 |
| Barium | EPA MCL | 2,000 $\mu$g/L | | | | 70 - 80 |
| Boron | None | | 180 - 650 | 160 - 1,100 | 193 - 359 | 160 - 190 |
| Cadmium | SD Aquatic<br>Acute<br>Chronic | <br>3.7 $\mu$g/L[2]<br>1.0 $\mu$g/L[2] | <1 - 5 | <1 - <1 | 0.2 - 0.2 | <10 - <10 |
| Chromium[3] | SD Aquatic<br>Acute<br>Chronic | <br>15 $\mu$g/L<br>10 $\mu$g/L | <1 - 4 | <1 - <1 | <1 - 4 | 20 - 30 |
| Copper | SD Aquatic<br>Acute<br>Chronic | <br>17 $\mu$g/L [2]<br>11 $\mu$g/L [2] | <1 - 11 | <0.1 - 1 | <1 - 9 | <10 - <10 |
| Iron | EPA SMCL | 300 $\mu$g/L | | | | 10 - 15 |
| Lead | SD Aquatic<br>Acute<br>Chronic | <br>65 $\mu$g/L[2]<br>2.5 $\mu$g/L[2] | <5 - 11 | <1 - <1 | <1 - 5 | <50 - <50 |
| Manganese | EPA SMCL | 50 $\mu$g/L | | | | <10 - <10 |
| Mercury | SD Aquatic<br>Acute<br>Chronic | <br>2.1 $\mu$g/L<br>0.012 $\mu$g/L | <0.1 - 5.3 | <0.1 - <0.1 | <0.2 - 0.2 | <1 - <1 |
| Molybdenum | None | | <1 - 16 | 4 - 8 | <1 - 8 | 10 - 200 |
| Nickel | SD Aquatic<br>Acute<br>Chronic | <br>1400 $\mu$g/L [2]<br>160 $\mu$g/L [2] | | | | 10 - 20 |
| Selenium | SD Aquatic<br>Acute<br>Chronic | <br>20 $\mu$g/L<br>5 $\mu$g/L | <1 - 16 | <1 - 4 | <1 - 2.1 | |
| Silver | SD Aquatic<br>Acute<br>Chronic | <br>3.4 $\mu$g/L[2]<br>none | | | | <10 - 10 |
| Uranium | EPA MCL | 20 $\mu$g/L [4] | 3.9 - 44 | 7.6 - 25 | 1 - 34 | |
| Vanadium | None | | <1 - 6 | 2 - 15 | 1 - 21 | |
| Zinc | SD Aquatic<br>Acute<br>Chronic | <br>110 $\mu$g/L[2]<br>100 $\mu$g/L[2] | <10 - 76 | <10 - 5 | 5 - 20 | <10 - <10 |

Sources: South Dakota Department of Environment and Natural Resources, 1998; EPA, 1996.

[1] Based on one route of exposure—ingestion of contaminated aquatic organisms only.
[2] Based on a $CaCO_3$ hardness of 100 mg/L.
[3] Standard based on Chromium VI; dissolved chromium in the river would mostly be in this form.
[4] Equivalent to 15 pCi/L.

exceeded it. It should be noted that Cottonwood Creek was a background site in the NIWQP study and that selenium is common in the marine shale soils of the area.

The CRST study measured *total* trace elements—less biologically available than dissolved trace elements—in the river downstream of the Belle Fourche River, outside of the influence of the District. The range of findings is shown in Table 3.13. These values are not comparable to the aquatic standards, since the latter are based on dissolved concentrations.

**Table 3.13: Total Trace Elements in the River** (mg/L)

| Trace Element | Range |
|---|---|
| Arsenic | 0.005-0.052 |
| Barium | 0.04-0.83 |
| Cadmium | <0.0005-0.0005 |
| Chromium | <0.010-0.016 |
| Copper | <0.10-0.024 |
| Iron | 0.42-19.80 |
| Lead | <0.002-0.006 |
| Manganese | 0.04-0.35 |
| Mercury | <0.0002-0.0019 |
| Nickel | <0.005-<0.030 |
| Selenium | 0.002-0.005 |
| Silver | <0.005-<0.010 |
| Zinc | <0.02-216.0 |

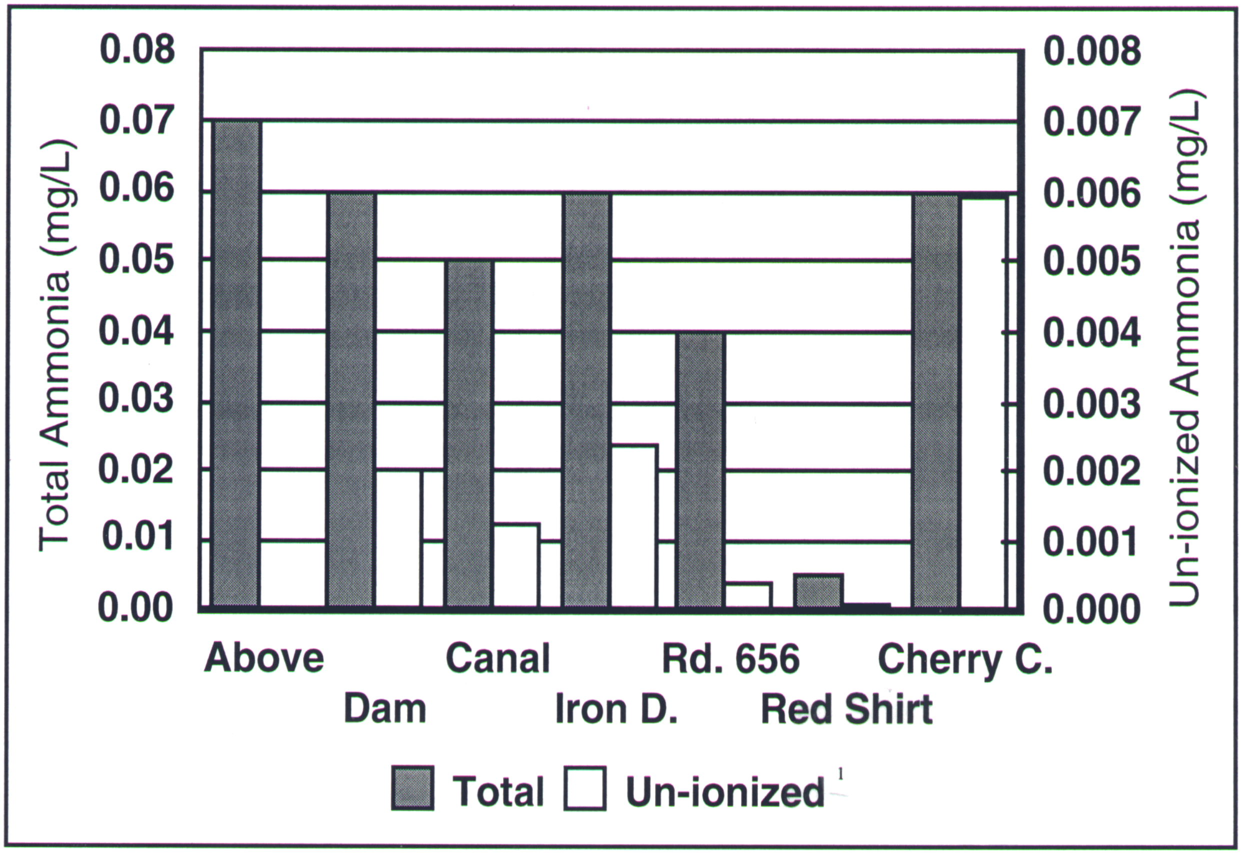
Results of the 1998 NIWQP sampling indicate that return flows had relatively low concentrations of trace elements. Greene et al. (1990) concluded that "there appeared to be minor difference between concentration of trace elements in water of the Cheyenne River upstream of irrigated land and in water downstream from all irrigation return flows" (p. 55).

***Nitrogen***

Nitrogen can be measured in water as nitrite, nitrate, ammonium, and total *Kjeldahl nitrogen* (that is, nitrogen determined by the Kjeldahl analytical method, which includes organic nitrogen and ammonium). Natural sources—fertilizers, barnyards, confined feedlots, and septic tanks— add nitrogen to the environment. Nitrate is the most common form in water. Because nitrate is highly soluble, fertilizer application followed by heavy rainfall or irrigation can cause transport. Concentrations in drinking water above EPA's MCL of 10 mg/L can cause health problems, especially in pregnant women or children younger than six months.

NIWQP samples were analyzed for nitrate plus nitrite (also with an MCL of 10 mg/L). Concentrations found were 1.2 mg/L at Cheyenne River at Buffalo Gap and at 1.3 mg/L at Cheyenne near Fairburn. Reclamation samples generally showed higher concentrations at the Cheyenne River near Hot Springs and at the District's canal. Samples from downstream sites fell within the same range as the NIWQP study, however. The highest concentrations of nitrate plus nitrite were 2.4-4.3 mg/L found at Iron Draw, which was also the only site with a measurable nitrite concentration of 0.3 mg/L.

Total ammonia concentrations were collected at seven sites in the Angostura area in 1997. From these, un-ionized ammonia was calculated based on temperature and pH as shown in fig. 3.4.




[1] Un-ionized scale 1/10 of total scale.

**Fig. 3.4: Ammonia Found at Seven Sites in the Cheyenne River basin**

Un-ionized ammonia can be toxic to aquatic life at 0.02-0.05 mg/L depending on stream temperature. From the figure, it can be seen un-ionized ammonia is only a small proportion of the total ammonia found in the samples. Concentrations are well below the toxic level.

#### ***Pesticides***

Pesticides—which can be transported in water and thus affect the environment and human health—were sampled at the season of application as part of the original 1988 NIWQP study (Greene et al. 1990). *Atrazine*, *cyanazine*, *prometon*, and *simazine* were the only pesticides found above detectable concentrations.

About half the NIWQP samples reported detectable concentrations of atrazine, with the maximum being 0.2 $\mu$g/L. Atrazine is a selective herbicide applied pre- or post-plant to control many broadleaf weeds in corn or sorghum (Ahrens 1994). It is highly soluble but readily decomposed by ultraviolet light (Ahrens, 1994). It is classified as slightly toxic. Cyanazine was detected in two NIWQP samples equal to the laboratory reporting limit. The highest concentration for a pesticide was prometon, detected in two samples with a maximum concentration of 1 $\mu$g/L.

Simazine, considered practically non-toxic (EXTOXNET 1996), was found in two of the nineteen NIWQP samples, with both being from samples taken in May. Samples collected from the Cheyenne River near Buffalo Gap contained 0.3 $\mu$g/L, while the sample from near Fairburn had a simazine concentration of 0.1 $\mu$g/L. EPA's drinking water standard is 4 $\mu$g/L.

Reclamation surveyed the District for current pesticide use and sampled six sites in 1997. Atrazine, cyanazine, prometon, and simazinewere sampled for, as well as *alachlor*, *ametryne-gesapax*, *methomyl*, *metribuzin*, *metolachor*, *premetryn*, *propham*, *sevin*, *simetryne*, *treflan*, *aldicarb*, *carbaryl*, *carbofuran*, and *oxamyl* (Appendix Q). None were found above detectable concentrations. Based on these analyses, pesticides in the Angostura area do not appear to exceed acceptable levels.

#### ***Edgemont Uranium Mill***

The decommissioned Edgemont Uranium Mill lies upstream of the reservoir near the town of Edgemont. The Tennessee Valley Authority bought the mill, tailings, and eight settling ponds in 1974, closing it down in 1978 without ever having operated it. According to the EIS done on closing the operation, all contaminated material was buried at the head of an ephemeral drainage 2 miles southeast of the mill, and contaminated sediment and bank material from Cottonwood Creek were removed and buried (U.S. Nuclear Regulatory Commission 1982).

Samples from the upper reach of the Cheyenne River and Cottonwood Creek from 1972-1997 indicated steady decreases in uranium concentrations from 1972-1974. The USGS sampled the Cheyenne River at Hot Springs for uranium four times in 1988, and twice at Edgemont in 1994. The Cheyenne River at Hot Springs gauge being downstream of the mill site should be representative of inflows into the reservoir. The Edgemont gauge, chosen for purpose of comparison, is upstream of both the mill site and Cottonwood Creek.

These samples showed that inflows into the reservoir seem to have been unaffected by any remnant of the uranium operation (Table 3.14). Both the average and maximum levels at Hot Springs were below the EPA drinking water standard for uranium of 15 pCi/L (pico-curies/cubic liter).

**Table 3.14: Uranium in the Cheyenne River Upstream of the Reservoir** (in pCi/L)

| | Edgemont (above the mill site) | Hot Springs (below the mill site) |
|---|---|---|
| Avg. | 20.5 | 8.2 |
| Max. | 25 | 12 |

## GROUNDWATER

Concerns were expressed by the public about effects of the alternatives on groundwater in the area. A spring and several shallow wells in the District are influenced by irrigation water. The spring, on the eastern end of the District, supplies livestock water to parts of the Buffalo Gap National Grasslands. It predates the District, and, since construction of the canals and irrigation of District lands, the spring has developed into a reliable source of water. It feeds a pond within the District from which water is pumped into a pipeline serving several thousand acres. The pipeline also serves as a wildlife water source. Fig. 3.5 is a schematic showing the relationship between canal leakage and return flows and groundwater in the District.

### Quantity

Wells in the District are found in shallow alluvium (U.S. Bureau of Reclamation 1996). Surface deposits over much of the irrigated lands are Late Cretaceous-ages marine shales (mostly Pierre Shale) overlain by small areas of alluvial deposits found mainly along the flood plains of Cascade Creek, Fall River, Horsehead Creek, Beaver Creek, Cottonwood Creek, and the Cheyenne River (Greene et al. 1990). Water movement above the Pierre Shale is shown in fig. 3.5.

USGS groundwater retrieval of less than 100 feet shows water levels vary from about 6-70 feet in area wells. Most wells were last measured in 1946 before irrigation began in the District, but a few were measured in the late 1970s and 1980s (see Appendix U).

### Quality

Table 3.15 summarizes results of 43 groundwater samples taken downstream of the dam in the District in Fall River and Custer counties. Most were collected in 1979, with a few collected from 1954-1995. Averages, maximums, and minimums of the samples are

**Table 3.15: Characteristics of Groundwater in the Area**

| | Conductivity [1] | Arsenic ($\mu$g/L) | Zinc ($\mu$g/L) | Selenium ($\mu$g/L) | Nitrate NO3-N (mg/L) | Mercury ($\mu$g/L) | Depth of well (feet) |
|---|---|---|---|---|---|---|---|
| Avg. | 1980 | 0.9 | 75.5 | 1.6 | 0.6 | 0.2 | 120.8 |
| Max. | 4940 | 11 | 1157 | 12 | 1.6 | 0.76 | 940 |
| Min. | 300 | 0.5 | 4 | 0.2 | 0 | 0.1 | 19 |
| EPA Standard | 750[2] | 50 | 5,000 | 50 | 10 | 2,000 | |

Source:EPA STORET Retrieval as of August 14, 1998.

[1] $\mu$/mho/cm @ 25º C.
[2] Converted from EPA's SMCL .

included the table, all of which were within EPA's drinking water standards (also included in the table). Appendix R details groundwater sampling (a location map is also available in Reclamation's Rapid City Field Office). USGS also collected samples from 19 wells in the Pierre Shale formation in 1988-1989. Average, maximum and minimum arsenic concentrations were found to be less than 1 $\mu$g/L (Greene et al. 1990). Average zinc concentration was 20 $\mu$g/L, maximum 57 $\mu$g/L, minimum less than 10 $\mu$g/L, while average, maximum, and minimum selenium concentrations were less than 1$\mu$g/L. All of these are also within EPA's drinking water standards.

Little data is available on groundwater quality in the District, but the effects of irrigation on groundwater can be inferred. Greene et al. (1990) evaluated District groundwater by analyzing data from several aquifers within the Hot Springs topographic quadrangle. EC and an estimated TDS using a conversion factor of 0.7 (the approximate ratio of TDS:EC in the water of Fall River and Beaver Creek, both of which are heavily influenced by groundwater accretions) are shown in Table 3.16.

Based on surface water data from the District, Greene et al. concluded that groundwater quality in those aquifers was similar to that of the District (1990). Data from District wells (Table 3.16) indicate that groundwater quality is slightly better on average than that of the aquifers measured upstream, based on EC and estimated TDS (from the conversion mentioned above).

This analysis might indicate that wells in the District are drilled into different aquifers than those sampled by Greene et al.

**Table 3.16: EC and TDS in District Groundwater**

| Location | **EC** ($\mu$mho/cm) | **TDS** (mg/L) |
|---|---|---|
| Alluvial Groundwater in Hot Springs Quadrangle | 2,380[1] | 1,670[1] |
| Shallow Bedrock Groundwater in Hot Springs Quadrangle | 2,180[1] | 1,530[1] |
| Groundwater under the District | 1,980[2] | 1,390[2] |

[1] Source: Greene et al. 1990.
[2] Source: EPA STORET Retrieval as of August 14, 1998.

## SEDIMENT

Storage is lost in all reservoirs to the natural build-up of sediment transported by inflows, and Angostura Reservoir is no exception. Gradual loss of storage affects the water available for future uses. Concerns were also expressed by the public about the effect of sediment on water quality.

### Quantity

The reservoir's original area-capacity relationship (see Table 3.3) was applied to Reclamation's DISSED computer model to predict future sedimentation in the reservoir. This model, developed to simulate sediment distribution in large reservoirs by the *Empirical Area Reduction* method, follows the procedures outlined in *Reservoir Sedimentation Guideline* (U.S. Bureau of Reclamation 1962) and detailed in the *Revision of the Procedure to Compute Sediment Distribution in Large Reservoirs* (U.S. Bureau of Reclamation 1982). Area capacities for 1997 and 2042 were predicted, with estimated sediment accumulation to continue at 985 AF/year, much less than originally estimated. Total sediment for the 1949-2042

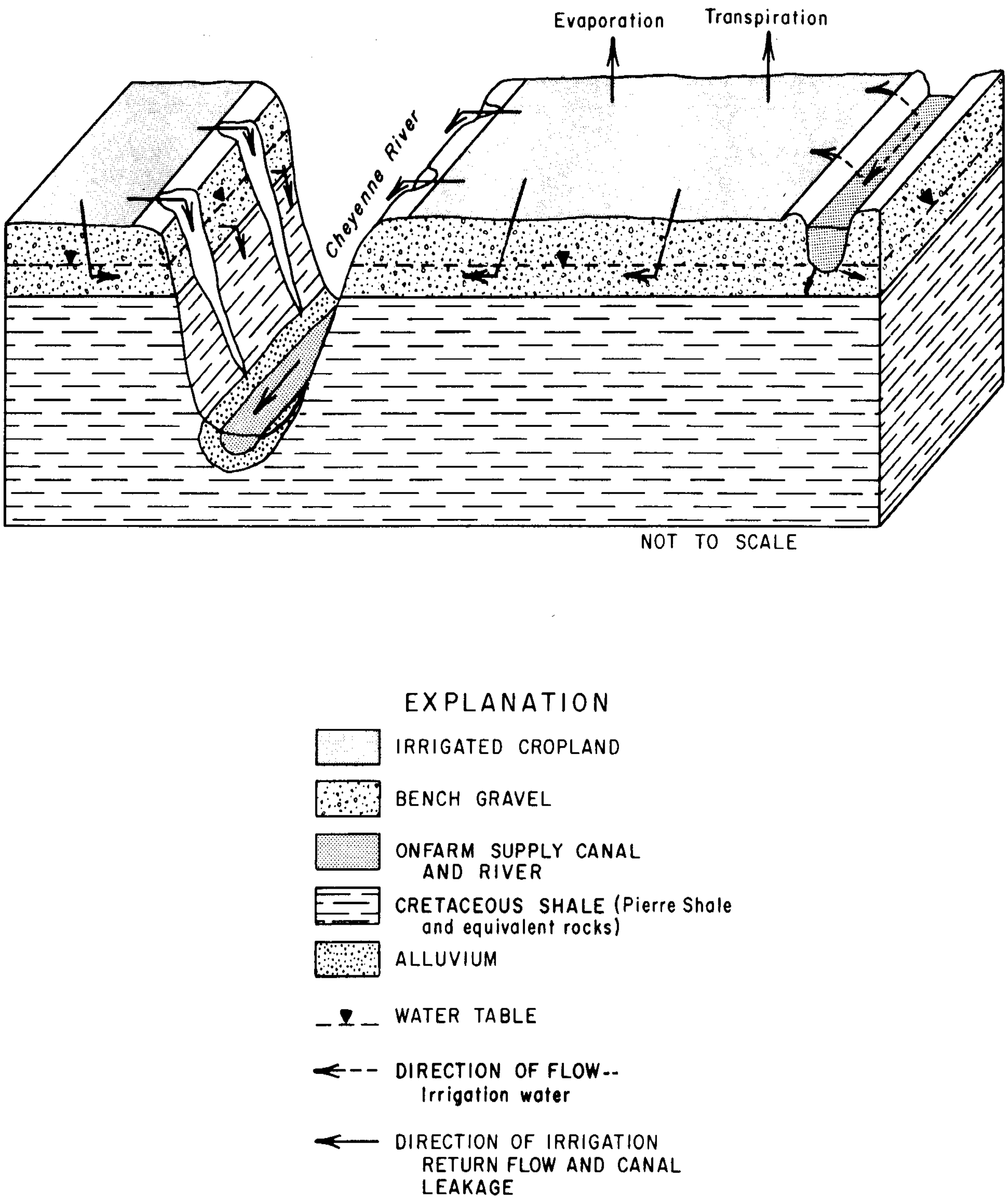



**Fig. 3.5: Schematic of Irrigated Land in the District**

Source: Greene et al. 1990.

period was estimated to be 91,605 AF, indicating a capacity loss of about 57%. Total capacity at elevation 3187.2 feet in 2042 would be 68,314 AF (the original capacity of 159,919 AF minus 2042 sediment of 91,605 AF), with active capacity of about 61,000 AF (2042 capacity of 68,314 AF minus inactive storage of 7,257 AF).

DISSED manual input and output data examples and a reservoir capacity/sediment distribution graph from the program are available from Reclamation's Rapid City Field Office (see Appendix I).

**Quality**

Studies by NIWQP, Reclamation, the OST, and CRST were used to analyze sediment quality in the reservoir and in the river downstream. The NIWQP database includes nine sites between USGS's Edgemont gauge and Red Shirt. Reclamation collected river sediment samples in August 1997 to update this database, resampled four of the NIWQP sites, and sampled three other NIWQP sites where water or aquatic species had been sampled but not the sediment. Locations and site numbers (assigned the NIWQP equivalent) were:

- 4a Angostura Reservoir Inflow Site
- 4b Angostura Reservoir Horsehead Creek Arm
- 4c Angostura Reservoir near the Dam
- 6 Angostura Canal
- 6S Angostura Canal split
- 9 Topeska's Pond
- 10 Iron Draw
- 11 Kimmie's Pond
- 12 Cheyenne River near Custer County Road 656 Bridge
- 14 Cheyenne River near Fairburn (Red Shirt)

Two additional sites—Cheyenne River at Rapid Creek (CRRC) and Cheyenne River at Cherry Creek (CRCC)—were sampled downstream from the NIWQP area to supplement the data and extend the area of study to near the confluence with the Missouri River.

No data is available for sediment in the tributaries to the Cheyenne or in return flows. Sediment from surface return flows would be similar to the area over which they flow, while groundwater return flows would contain very little sediment (see Appendix Q).

Bed sediment generally is derived from eroded soils. Samples of the sediment indicate constituents available for dissolution or re-suspension in water, as well as concentrations available to plants and animals. The NIWQP study compared bed sediment samples to conditions expected in western soils of the region (Shacklette and Boerngen 1984). The NIWQP study collected one sample from each of nine sites in 1988, and a sample from each of four sites in 1994. Reclamation collected bed-sediment samples at seven sites in 1997. The CRST began monitoring sediment in 1994: Samples from CRST sites near Cherry Creek were included in this analysis. Findings of these studies in comparison to a western soils baseline are shown in Table 3.17.

The NIWQP found selenium concentrations at the upper end of the baseline range. The maximum selenium concentration—at 10 times the upper end of the baseline—was from Cottonwood Creek near Buffalo Gap, an unirrigated background site. This site also had the highest selenium concentration in water. Other results were all within the baseline range.

Bed-sediment concentrations from the Reclamation study were generally within the baseline range. One selenium concentration and several molybdenum concentrations were slightly above the baseline, however, and one zinc concentration was found nearly double the baseline maximum (Table 3.17). One arsenic concentration found at the Cheyenne River near

**Table 3.17:Characteristics of Sediment Quality in the Area** ($\mu$g/L)

| | Western Soils Baseline | NIWQP | Verification Study | Reclamation | CRST |
|---|---|---|---|---|---|
| Arsenic | 1.2 - 22 | 6.2 - 15 | <10 - 19 | 4.9 - 104.3 | 17 - 44 |
| Barium | 200 - 1,700 | 150 - 1,700 | 730 - 1,100 | 47 - 615 | No data |
| Boron | 5.8 - 91 | 1.2 - 7.3 | | 4 - 27 | No data |
| Cadmium | | <2 - 2 | <2 - <2 | 0.2 - 1.9 | 0.4 - 1.2 |
| Chromium | 8.5 - 200 | 20 - 85 | 6- 30 | 2 - 27 | 2 - 29 |
| Copper | 4.9 - 90 | 8 - 28 | 2 - 10 | 7 - 29 | 10- 28 |
| Lead | 5.2 - 55 | 12-55 | 17-28 | 19 - <167 | 9 - 20 |
| Manganese | | 220 - 1,800 | 23 - 610 | | 333 - 2,640 |
| Mercury | 0.0085 - 0.25 | <0.02 - 0.04 | | <0.1 - <0.1 | <0.1 - <0.1 |
| Molydenum | 0.18 - 4.0 | <2-2 | <2-<2 | 3 - 7.5 | No data |
| Nickel | 3.4 - 66 | 4 - 29 | 7 - 18 | 11 - 39 | 13.5 - 30 |
| Selenium | 0.039 - 1.4 | 0.6 - 14.0 | <1 - <1 | 0.2 - 1.9 | No data |
| Uranium | 1.2 - 5.3 | 1.9 - 5.3 | <100 - <100 | 2.5 - 17.8 | No data |
| Vanadium | 18 - 270 | 31 - 200 | 13 - 75 | 11 - 46 | No data |
| Zinc | 17 - 180 | 39 - 140 | 25 - 64 | 24 - 317 | 44.5 - 103 |

Source: Shacklette and Boerngen 1984.

Cherry Creek and the CRST study arsenic results were higher than baseline. This probably was due to effects of arsenic-contaminated sediment transported from Whitewood Creek.

## STREAM CORRIDOR

Effects of the alternatives on the stream corridor along the Cheyenne River downstream of the dam was a major concern of the public. The stream corridor includes the stream channel itself and nearby riparian areas. Within the stream corridor, the channel and its flood plain are primarily formed and maintained through erosion, transport, and deposition of sediment by river flows (FISRWG 1998). Flows and sedimentation are therefore defining processes of stream corridors. Riparian areas exist at the joining of aquatic and upland ecosystems. For many western streams, riparian areas are a narrow band bordering the stream channel. Most riparian studies focus on plant communities; in this EIS, however, focus was the on stream corridor, and, in addition to vegetation, on selected aspects of flows and sediment deposits. This approach was decided upon because of the linkage between parts of the system: Flows, for example, dictate sediment transport, erosion, and deposition. Because riparian vegetation often is found on sediment deposits, changes in flows can also result in changes to vegetation, both directly and through changes in sediment deposits.

To understand how Angostura Dam affects the stream corridor, it is first necessary to understand how stream systems function. Meandering streams—such as the Cheyenne—have active channels that move within the flood plain by depositing sediment as point bars (on the inside of river curves, or *meanders*) and eroding the outside banks of meanders (Johnson 1992; Friedman et al. 1998). Point bars and other sediment deposits become seedbeds for future cottonwood and willow regeneration, while erosion often removes vegetation. As new vegetation establishes on a point bar, high flows may deposit more sediment and raise the bar's elevation . If sediment becomes high enough and vegetation large enough to withstand high flows, then it may continue to grow and mature until future channel meanders intersect, erode the site, and re-initiate the cycle. In unregulated western streams, erosion and deposition of sediments result in a diverse pattern of different-aged stands of riparian vegetation dominated by cottonwood and/or willows.

Stream channels function within a range of flows, sediment movement, and other factors dictated by conditions. If there are no large changes in flows and available sediment, the channel reaches a condition of balance—the volume of water and sediment entering the channel equal the water and sediment leaving the channel downstream, for example—a condition referred to as an equilibrium, or, because of natural variation, a *dynamic equilibrium* (FISRWG 1998). Changes in one or more of the channel factors, such as flows and/or available sediment, result in the stream adjusting to a new equilibrium supporting very different stream characteristics. Regulation by dams generally alters this pattern of seasonal flows by flattening periods of high flows and increasing flows during past periods (like winter) of low or no flows. The loss of high flows removes the dynamic process that would otherwise restructure the channel periodically and sustain different-aged plant communities.

Regulation also affects sediment supply. Given the idea of equilibrium, differences in some pre- and post-dam stream corridor characteristics should be expected, resulting from the channel adjusting to regulation-induced changes in flows and sediment.

The dam then affects flows, sedimentation, and the resources influenced by these processes within the river. Flows and sedimentation themselves affect many resources (a complete catalog of the relationship among flows, sediment, and other riparian resources is beyond the scope of this EIS—see Stanford et al. 1995; Poff et al. 1997; Johnson 1998). For this EIS, analysis focused on a small number of indicators and measurement units believed to reflect changes in the stream corridor from changes in operation of the dam. These indicators are *selected channel characteristics* and *riparian vegetation*.

## Selected Channel Characteristics

To better understand conditions in the stream corridor, selected Cheyenne River channel characteristics were examined as they currently exist and then compared to pre-dam conditions. It was assumed that differences between existing and pre-dam conditions would reflect how the river has adjusted to a new equilibrium. Aspects selected to represent channel characteristics include *flows*, *sediment*, and *length* of the stream.

### *Flows*

As a first step in understanding how regulation has affected river resources, USGS stream gauge records were searched for flow information. While many gauges can be found along the river (see fig. 3.1), only the Wasta gauge provided both pre- and post-dam flows. Post-dam data were divided into 15-year blocks corresponding to the 15 years of pre-dam data as shown in Table 3.18. The basic trends discussed would hold if the pre-dam data (15 years) were compared to the 45 years of post-dam data.

Data reflect a general reduction in annual flows at Wasta following construction of Angostura Dam. The increment attributable to the dam, however, cannot be determined. The drainage area represented at the Wasta gauge is about 12,800 square miles, while the drainage area at the dam is 9,100 square miles, the area at Edgemont 7,143 square miles (see Table 3.1). Also, Rapid Creek joins the river a few miles upstream from the Wasta gauge, which complicates interpretation. Rapid Creek flows were also being affected by Deerfield Dam (completed in 1947) and Pactola Dam (1956) during the post-Angostura Dam period of record at Wasta.

The matter is further complicated by the fact that the Cheyenne River is regulated not only by Angostura Dam and dams on the tributaries, but also by many private stock ponds and other impoundments in the basin (see "Surface Water Quantity" in this chapter). While the data indicate a general decrease in annual flows following dam construction, the exact cause probably results from a combination of factors. Thus analysis of flows at Wasta provides only a general indication of how flows might have been altered by the dam. Data shown in Table 3.18 could have been affected in any of the 15-year periods by climatic events that increase or reduced flows.

In addition to lower annual flows, a change in seasonal flow patterns has also occurred. When the monthly data were combined into three-month periods—winter (January, February, March), spring (April, May, June), summer (July, August, September), and fall (October, November, December)—patterns begin to appear as shown in Table 3.19. The largest reductions in flows have occurred in spring and summer, while flows have increased in the fall. If monthly data were selected that better fit the period of historic low flows (November-January) and compared to fall data (October-December), then the percentage increase over pre-dam flows is larger in all post-dam periods, except for 1980-1994. A similar adjustment to better fit historic high flows (May-July) indicates that a pattern of decreasing flows continues, as does the pattern for June (Table 3.19). June showed the greatest difference between pre- and post-dam flows.

Flow characteristics define the stream channel, as mentioned. Peak flows restructure the channel and provide bare areas of sediment suitable for establishment of new stands of cottonwoods and/or willows. A change in the frequency of peak flows would be expected to affect sediment deposit and riparian vegetation. Table 3.20 shows that frequency of channel-modifying flows above 5,000 cfs and above 10,000 cfs at Wasta have declined. The percent reduction is greater for intermediate flows (above 5,000 cfs) than for larger flows (above 10,000 cfs). The dam undoubtedly affects distribution and magnitude of peak flows, and some attenuation of all peak flows probably occurs as flows pass downstream and by the Wasta Gauge. Because of the limited storage at Angostura Reservoir, however, many of the larger peak flows probably pass through the reservoir unaltered.

Occurrence of peak flows, although reduced in frequency from pre-dam conditions, would provide some semblance of the river's historic dynamics (that is, exposed sediment—see below). These changes in river dynamics are likely linked to expansion of water impoundments (Angostura Reservoir, tributary reservoirs, and many smaller livestock impoundments), direct surface diversion, groundwater pumping, and channel alteration.

**Table 3.18: Average Monthly Flow Computed from Data at the Wasta Gauge for Pre-Dam (1935-1949) and Post-Dam (1950-1994)**

| | Avg. 1935-1949 | | Avg. 1950-1964 | | Avg. 1965-1979 | | Avg. 1980-1994 | |
|---|---|---|---|---|---|---|---|---|
| Jan. | 74.11 | 4,556.56 | 82.71 | 5,085.88 | 96.36 | 5,925.16 | 103.81 | 6,383.05 |
| Feb. | 167.85 | 9,389.09 | 140.51 | 7,891.17 | 146.43 | 8,181.42 | 169.38 | 9,480.71 |
| March | 547.83 | 33,684.89 | 297.88 | 18,315.90 | 416.57 | 25,613.75 | 395.71 | 24,329.52 |
| April | 532.66 | 31,695.73 | 237.89 | 14,155.50 | 525.02 | 31,240.86 | 315.63 | 18,782.07 |
| May | 992.87 | 61,049.12 | 514.22 | 33,967.21 | 737.55 | 45,350.35 | 678.64 | 41,727.75 |
| June | 1,537.79 | 91,504.66 | 829.60 | 49,364.49 | 1,041.76 | 61,989.15 | 570.95 | 33,973.37 |
| July | 623.42 | 38,332.83 | 315.95 | 19,426.79 | 386.87 | 23,787.90 | 222.56 | 13,685.43 |
| Aug. | 214.41 | 13,183.74 | 159.78 | 9,824.32 | 181.80 | 11,178.58 | 130.97 | 8,051.65 |
| Sept. | 149.74 | 8,910.15 | 156.43 | 9,308.16 | 130.44 | 7,761.85 | 135.61 | 8,069.51 |
| Oct. | 113.26 | 6,963.83 | 103.57 | 6,368.53 | 141.97 | 8,729.52 | 177.21 | 10,896.51 |
| Nov. | 114.76 | 6,828.56 | 109.58 | 6,520.46 | 130.85 | 7,786.45 | 133.09 | 7,915.81 |
| Dec. | 79.99 | 4,918.61 | 98.16 | 6,037.55 | 105.05 | 6,458.97 | 104.71 | 6,438.07 |
| Avg. Monthly | 429.06 | 25,918.15 | 253.86 | 15,522.17 | 336.72 | 20,333.66 | 261.52 | 15,811.12 |
| Avg. Annual AF | | 311,017.77 | | 186,265.98 | | 244,003.96 | | 189,733.46 |

**Table 3.19: Average Monthly Flows in the River, Pre- and Post-Dam**

| | Pre-Dam 1935-1949 | Post-Dam 1950-1964 | | Post-Dam 1965-1979 | | Post-Dam 1980-1994 | |
|---|---|---|---|---|---|---|---|
| | Avg. AF | Avg. AF | % Change from Pre-Dam | Avg. AF | % Change from Pre-Dam | Avg. AF | % Change from Pre-Dam |
| Winter (Jan.-March) | 15,876.85 | 10,430.98 | -34.3 | 13,240.11 | -16.6 | 13,397.76 | -15.6 |
| Spring (April-June) | 61,416.50 | 32,495.73 | -47.1 | 46,193.45 | -24.8 | 31,494.40 | -48.7 |
| Summer (July-Sept.) | 20,142.24 | 12,853.09 | -36.2 | 14,242.78 | -29.3 | 9,935.53 | -50.7 |
| Fall (Oct. Dec.) | 6,237.00 | 6,308.85 | 1.1 | 7,658.31 | 22.8 | 8,416.80 | 34.9 |
| Historic Low Flows | 5,434.58 | 5,881.30 | 8.2 | 6,723.53 | 23.7 | 6,912.31 | 27.2 |
| Historic High Flows | 63,628.87 | 34,252.83 | -46.2 | 43,709.13 | -31.3 | 29,795.52 | -53.2 |
| June | 91,504.66 | 49,364.49 | -46.1 | 61,989.15 | -32.3 | 33,973.37 | -62.9 |

**Table 3.20: Number of Flows Greater than 5,000 cfs and 10,000 cfs at Wasta, Pre-Dam and Post-Dam**

| Period | Number of Flows >5,000 cfs | Number of Flows >10,000 cfs |
|---|---|---|
| 1935-1949 | 58 | 14 |
| 1950-1964 | 28 | 8 |
| 1965-1979 | 37 | 12 |
| 1980-1994 | 19 | 7 |

#### *Sediment*

In addition to reduced flows, the Cheyenne River has probably experienced a reduction in volume of sediment transported through the stream corridor. For example, about 29,151 AF of sediment was trapped by the reservoir from 1949-1979 (see "Sediment: Quantity" in this chapter). This sediment is no longer available for transport downstream, so releases, seepage, or spills from the reservoir are relatively sediment-free.

#### *Length*

Channel balance is maintained between the stream's energy (interaction of flows and slope) and size and volume of sediment moved (FISRWG 1998). If, for instance, the volume of sediment entering the stream corridor were reduced—perhaps trapped behind a dam—then the channel would probably adjust through flattening its slope, if all other variables remained constant. However, all variables do not remain constant, so prediction of channel adjustment presents a challenge. For purposes of this EIS, present conditions can be measured, compared to pre-dam conditions, and used to explain the channel's response.

Channel length over a given distance can be used as an indirect measure of channel slope. Basically, the flatter the slope, the more sinuous the channel; conversely, the steeper the slope, the straighter the channel. The river channel was measured on 1948 and 1991 aerial photos in 25-mile increments for 200 miles downstream of the dam. The results showed that channel length increased from about 185 miles in 1948 to about 199 miles in 1991, a 7.5% increase (Ahlers and Armbruster 1993). It appears the channel slope of the Cheyenne River has flattened in response to reduced flow and available sediment. This results from a combination of factors, including construction of the dam.

### Riparian Vegetation

Unregulated western rivers often experience high spring snow-melt flows and occasional intense summer rainfall, often high enough to restructure sediment deposits and erode vegetation established since previous high flows. Dynamic flows ensure that sediment and vegetation are constantly changing.

Regulation can affect many channel characteristics and associated riparian vegetation. To understand existing riparian vegetation conditions, selected reaches of the Cheyenne River were examined as they are now, and then compared to pre-dam conditions. High quality black-and-white aerial photographs of the river from October-November 1948 were used to represent pre-dam conditions, while July-August 1991 photographs represented post-dam conditions at present. Fig. 3.6 is a GIS presentation based on aerial photos of the Red Shirt area for the two periods.

It was assumed that differences between present and pre-dam conditions reflect how riparian vegetation has responded to regulation of the river. Aspects selected included the area (acres) of *exposed sediment* within the channel, *area coverage* (acres) of riparian vegetation, number of *vegetated polygons* (or patches) within the flood plain, and area (acres) of change in various classes of vegetation *canopy closure*.

Various means to measure riparian vegetation can be used to show how the stream corridor has changed. Reduced flows, for example—especially reduced peak flows—have probably permitted vegetation to establish on exposed sediment deposits. Areas of exposed sediment deposits would thus be expected to decline and areas of vegetation to increase following dam construction. Vegetation (cottonwood and willow) establishment on exposed sediment would also result in more vegetated polygons within the stream corridor. Finally, canopy closure, or the percentage of ground surface hidden by foliage in aerial photographs, was used as a gross estimate of age. It was assumed, for instance, that polygons supporting dense cover (81-100% closure) are young recently-established cottonwood and willow, while polygons supporting open cover (1-20% closure) are mature stands.

***Exposed Sediment***

Areas of exposed sediment (non-vegetated in-channel sediment deposits) were determined from river photographs for a length of 200 miles below the dam under similar flows in 1948 and 1991. (Sediment could result from high flows occurring 1-2 years before the photos were taken.) Areas of exposed sediments declined from 13,784 acres in 1948 to 7,156 acres in 1991, a decline of 48% (U.S. Bureau of Reclamation 1998). Table 3.21 shows the acres of exposed sediment.

***Area Coverage***

Areas of riparian vegetation within the flood plain were also determined from photographs for a length of the river 200 miles below the dam under similar flows in 1948 and 1991 (fig. 3.6). Areas of riparian vegetation increased from 18,030 acres in 1948 to 22,997 acres in 1991 (as shown in Table 3.21), an increase of 27.5% (U.S. Bureau of Reclamation 1998).

**Table 3.21: Exposed Sediment and Vegetation Coverage, and Total by 25-River Mile Increments below Angostura Dam** (ac.)

| Miles Be low Dam | 1948 | | | 1991 | | |
|---|---|---|---|---|---|---|
| | Exposed Sediment | Vegetation Coverage | Total Area | Exposed Sediment | Vegetation Coverage | Total Area |
| 1-25 | 717 | 420 | 1,137 | 319 | 800 | 1,119 |
| 26-50 | 1.103 | 2,010 | 3,113 | 429 | 2,226 | 2,655 |
| 51-75 | 1,173 | 2,512 | 3,685 | 693 | 2,745 | 3,438 |
| 76-100 | 1,437 | 2,698 | 4,135 | 878 | 2,892 | 3,770 |
| 101-125 | 1,670 | 2,814 | 4,484 | 990 | 2,894 | 3,884 |
| 126-150 | 1,856 | 3,153 | 5,009 | 1,129 | 3,847 | 4,976 |
| 151-175 | 3,163 | 2,689 | 5,852 | 1,458 | 4,316 | 5,774 |
| 176-200 | 2,665 | 1,734 | 4,399 | 1,260 | 3,277 | 4,537 |
| **Totals** | 13,784 | 18,030 | 31,814 | 7,156 | 22,997 | 30,153 |

Fig. 3.6

# ANGOSTURA UNIT BELOW DAM

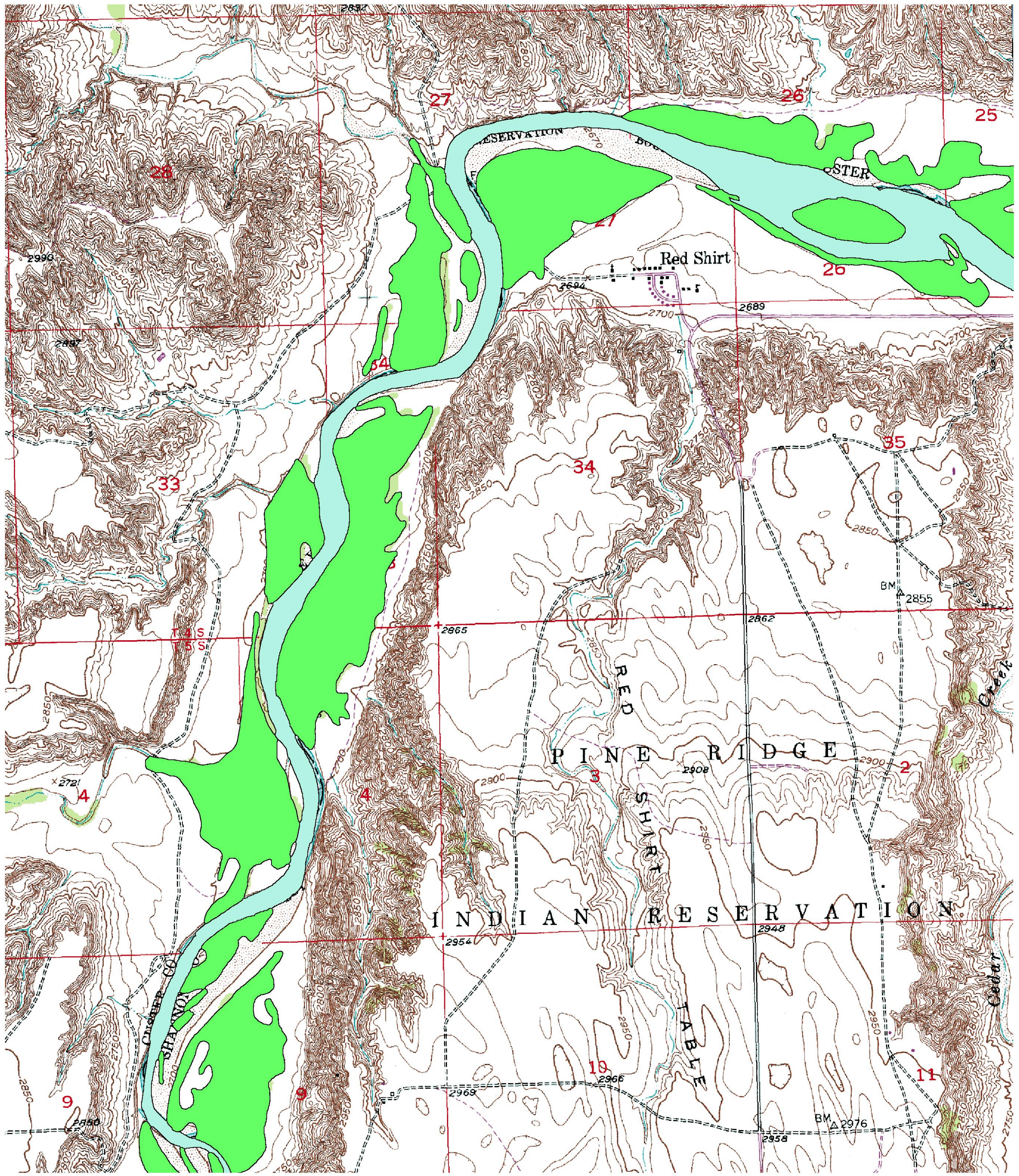
## RIPARIAN HABITAT AND RIVER CHANNEL CONFIGURATION CHANGES

Dakotas Area Office GIS

LEGEND

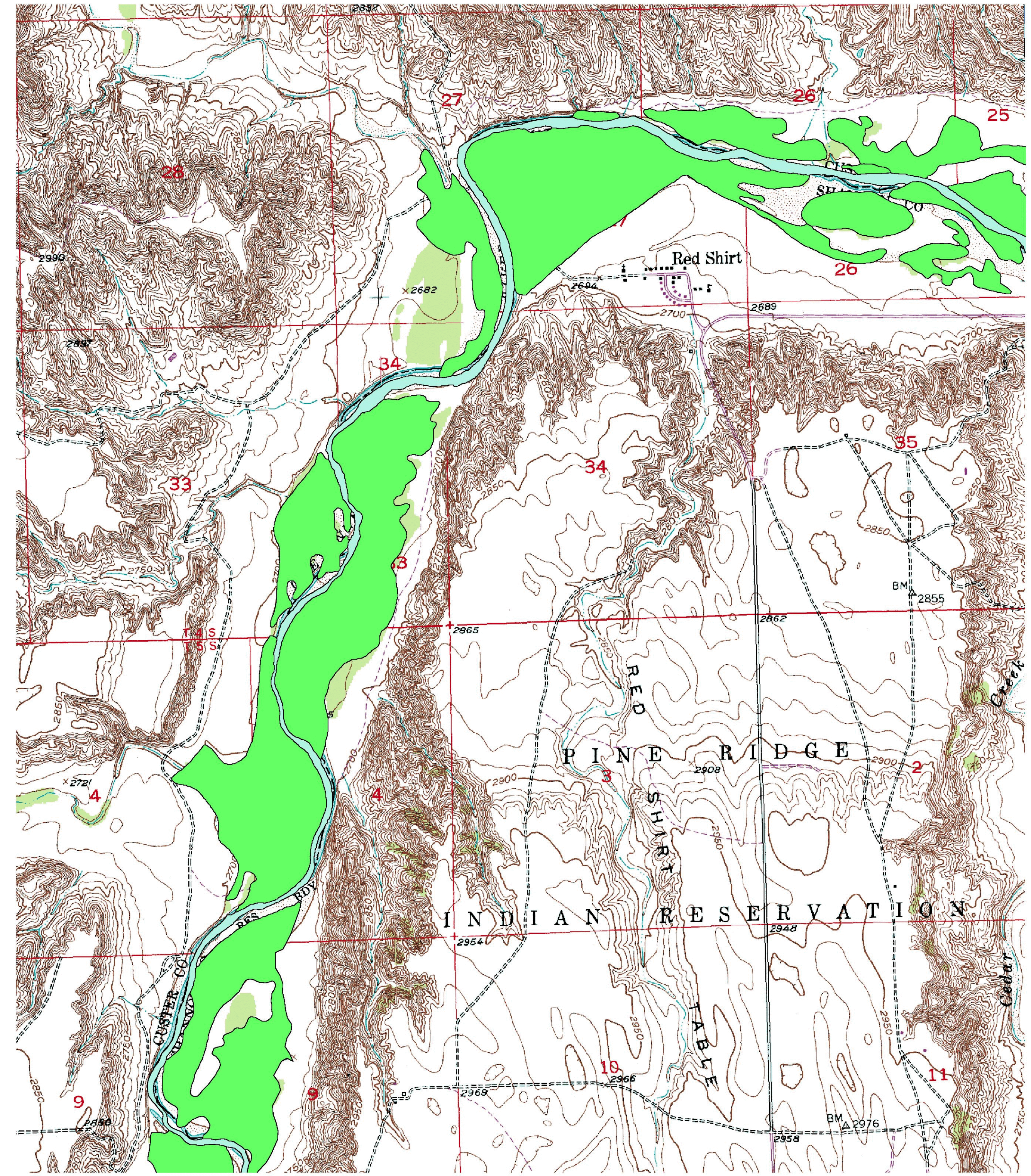
- RIVER
- VEGETATION

### 1948 PRE DAM CONDITONS




SUM OF VEGETATIVE ACREAGE
1948 AREA DISPLAYED = 678.5 ACRES
1948 TOTAL ACREAGE = 3265.3 ACRES

### 1991 POST DAM CONDITONS




SUM OF VEGETATIVE ACREAGE
1991 AREA DISPLAYED = 790.9 ACRES
1991 TOTAL ACREAGE = 3870.3 ACRES

0 0.5 1 1.5 2
MILES

Date: 14-SEP-2000
e:/data/angostura/dendata/angst/vegdata/map48-91

Decreases in exposed sediment and increases in riparian vegetation are probably linked. For purposes of analysis, the 200 miles below the dam was divided into 25-mile increments. Changes over time in these increments were noted, including total changes in areas of sediment and vegetation. This process allowed the conclusions in Table 3.21 to be drawn . In general, while areas of exposed sediment declined and areas of vegetation increased from 1948-1991, the total combined area in sediment and vegetation remained similar.

#### *Vegetated Polygons*

The number of vegetated polygons within the flood plain was determined from river photographs for 200 miles below the dam under similar flow conditions in 1948 and 1991. This number increased from 841 in 1948 to 1,113 in 1991, an increase of 32% (U.S. Bureau of Reclamation 1998). If vegetation has increased through occupation of exposed sediment as postulated above, then the number of vegetated polygons would increase as indicated by these data.

#### *Percent Canopy Closure*

The dominant woody plant found in the riparian zone is cottonwood. Small isolated bands of willows have established immediately next to the banks of the river in some areas. Many of the stands are mature trees with open canopies (see "Wildlife" in this chapter).

Canopy closure was evaluated from photographs of the area to better understand riparian vegetation response to stream regulation. Vegetated polygons within the floodplain for 200 miles downstream of the dam were categorized by canopy closure as shown in Table 3.22. Sparsely vegetated (1-20% canopy closure) polygons were the most numerous category in photographs for both 1948 (15,126 acres) and 1991 (15,898 acres); this category increased by approximately 770 acres between 1948-1991. While all categories showed increases in area coverage, the 21-40% canopy closure category experienced the largest increase in area coverage. Although further study is needed, it is postulated that this category represents a large part of the trees that occupied exposed sediment deposits following construction of dam.

**Table. 3.22: Canopy Closure and Area of Riparian Vegetation below the Dam** (ac.)

| Canopy Cover (%) | 1948 | 1991 |
|---|---|---|
| 1-20 | 15,126 | 15,898 |
| 21-40 | 2,783 | 6,199 |
| 41-60 | 110 | 765 |
| 61-80 | 11 | 123 |
| 81-100 | 0 | 12 |
| **Totals** | 18,030 | 22,997 |

### WETLANDS

Wetlands—dominated by persistent emergent vegetation, emergent mosses or lichens, trees, and shrubs—constitute important wildlife habitat in the Angostura Area. Also, concerns were expressed by the public about wetlands.

While their number and acreage in the area are not great, wetlands add greatly to wildlife use and species diversity. A variety of waterfowl, upland game birds, songbirds, shorebirds and neo-tropical migrants use this habitat. Wetlands in the area have been grouped according to location, function, and type. These groups are:

- those in the reservoir
- wetlands surrounding the reservoir
- wetlands in the District
- riparian or riverine wetlands.

National Wetlands Inventory maps were used to determine acreages in each category as shown on fig. 3.7.

Angostura Reservoir is a man-made, deep water wetland with 4,612 acres of surface area at elevation 3187.2 feet. It provides some shallow-marsh habitat along the shore, primarily at the upper end. Wetlands also occur in uplands surrounding the reservoir. Natural depressions or small man-made impoundments, these wetlands rely on precipitation for their existence. About 376 acres of wetland can be found around the reservoir.

About 794 acres of wetlands are in the District along the river. These wetlands are greatly influenced by return flows through surface run-off and groundwater. Riparian or riverine wetlands occur along the Cheyenne River and within the flood plain. They are influenced by the river in one or more ways, being cut-off river meanders or oxbows, depressions that fill when the river floods, or river-influenced springs or fens. About 2,085 acres of riparian or riverine wetlands occur along the river. Of that total, the river makes up 1,617 of these acres, with 468 acres of wetlands proximate to the river.

## FISHERIES

Concerns were expressed by the public about effects of the alternatives on reservoir and river fisheries in general, with particular concern by the OST directed to fish health.

The Cheyenne River is a large warm water stream with variable flows, sandy substrate, and high turbidity and dissolved solids. Everman and Cox (1896) investigated the Cheyenne River in 1892-1893 to report on suitable sites for fish hatcheries in the region. They described the river as “ordinarily a shallow stream whose waters are always more or less alkaline and filled with solid matter in suspension from the extremely easily eroded country through which it flows ” (p. 336).

Fisheries in the Angostura area can be divided into three distinct river segments:

- Angostura Reservoir and upstream (upper Cheyenne River)
- the river from below the dam to its confluence with the Belle Fourche River (middle Cheyenne River)
- the river from its confluence with the Belle Fourche to Lake Oahe (lower Cheyenne River).

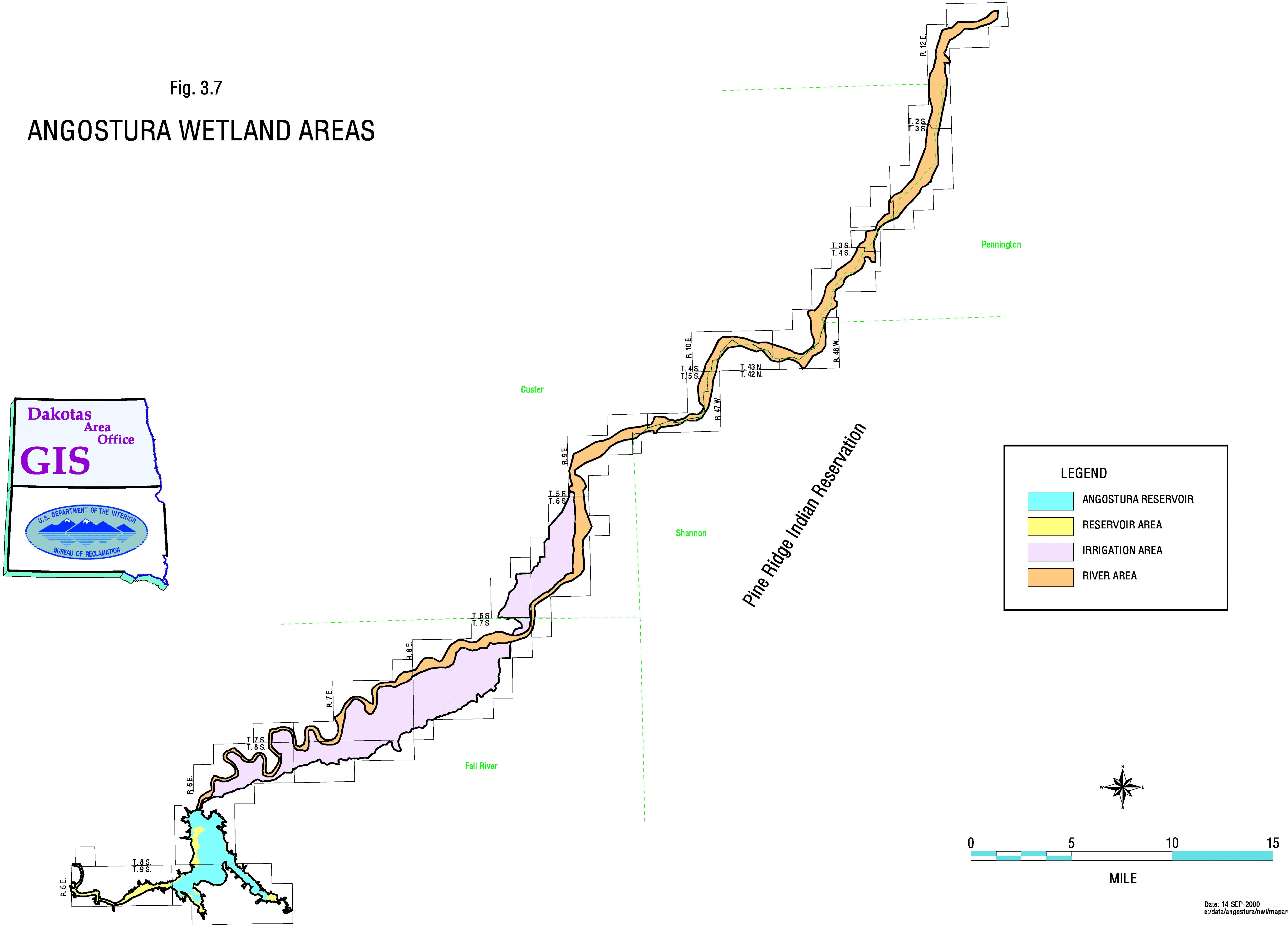
### Angostura Reservoir

Angostura Reservoir at elevation 3187.2 feet extends about 17 miles up the Cheyenne River and 7.6 miles up Horsehead Creek. The reservoir has 4,612 surface-acres at this elevation. Water elevations fluctuate greatly from month-to-month and year-to-year, depending on inflows and irrigation releases. Fluctuating water elevations prevent extensive development of aquatic vegetation, essential for fish spawning, as well as escape cover for larval fish. SDGF&P (South Dakota Game Fish and Parks Department) believe the fluctuating water elevations are responsible for the low reproductive success of gamefish and forage species at the reservoir (Lee Vanderbush, 1998: personal communication). While not extensive, some aquatic vegetation has developed in the inlets and shallows on the west side of the reservoir. Emergent vegetation includes cattails, willows, and smartweed, while submergent vegetation is primarily coontail and elodea.

SDGF&P instituted a fish stocking program because of low reproductive success. In recent years, walleyes and largemouth bass have been stocked. Emerald shiner and gizzard shad have also been introduced to supplement the forage base for game fish. Table 3.23 lists species

Fig. 3.7

# ANGOSTURA WETLAND AREAS



found in the reservoir, while Attachment 1 at the end of the EIS lists year, species, and approximate numbers stocked in the reservoir since construction.

**Table 3.23: Fish Species in the Reservoir**

| Common Name | Scientific Name |
|---|---|
| Walleye | *Stizostedion vitreum vitreum* |
| Largemouth bass | *Microptirus salmoides* |
| Emerald shiner | *Notropis atherinoides* |
| White sucker | *Catostomus commersoni* |
| Bluegill | *Lepomis macrochirus* |
| Gizzard shad | *Dorosoma cepedianum* |
| Smallmouth bass | *Microptirus dolomieui* |
| Channel catfish | *Ictalurus punctatus* |
| Black bullhead | *Ictalurus melas* |
| Yellow perch | *Perca flavescens* |
| Common carp | *Cyprinus carpio* |
| Northern pike | *Esox lucius* |
| Black crappie | *Pomoxis nigramaculatus* |
| Spottail shiner | *Notropis hudsonius* |
| Rockbass | *Ambloplites rupestris* |
| Green sunfish | *Lepomis cyanellus* |
| Northern redhorse | *Moxostoma aureolum* |
| River carpsucker | *Carpiodes carpio* |
| Fathead minnow | *Pimephales promelas* |

### Middle Cheyenne River

The river from below Angostura Dam to the confluence with the Belle Fourche River is typical of western streams after regulation and introduction of exotic fish species. Water is colder here than water downstream and less turbid since the reservoir acts as a settling basin. The stream bears considerable energy and erosive power. Reduced releases to the river since the dam was built—coupled with small contributions from tributaries—has resulted in a segment of the river that does not consistently flood to any great degree. The river channel thus shifts very little, with reaches that have eroded down to bedrock.

The fishery in this segment has also exhibited changes. Fish species requiring turbid water are found less frequently or not at all, having been replaced by fish species (many of them introduced exotics) preferring clear, less turbid water.

### Lower Cheyenne River

As the Cheyenne River flows towards Lake Oahe, turbidity and water temperature increase due to erosion, clay soils, a low stream gradient, and influence of large tributaries like the Belle Fourche River. This segment supports fish communities more tolerant of turbid warm-water conditions. The furthest downstream reaches are affected by Lake Oahe and its fish community.

Table 3.24 lists fish species identified in the middle and lower Cheyenne River, demonstrating change in species composition in the last 100 years. Surveys by Everman and Cox (1896); Churchill and Over (1933); and Bailey and Allum (1962) collectively documented 15 species of fish in the Cheyenne River (Hampton 1998). Surveys conducted by Hampton (1998) documented an additional 16 species.

**Table 3.24: Fish Species in the Cheyenne River Between the Dam and Lake Oahe**

| Common Name | Scientific Name |
|---|---|
| **Documented in Early Studies (Bailey and Allum 1962)** | |
| Flathead chub | *Platygobio gracilis* |
| Plains minnow | *Hybognathus placitus* |
| Sand shiner | *Notropis stramineus* |
| Channel catfish | *Ictalurus punctatus* |
| Shorthead redhorse | *Moxostoma macrolepidotum* |
| River carpsucker | *Carpiodes carpio* |
| Stonecat | *Noturus flavus* |
| Sturgeon chub | *Macrhybopsis gelida* |
| White sucker | *Catostomus commersoni* |
| Longnose dace | *Rhinichthys cataractae* |
| Fathead minnow | *Pimephales promelas* |
| Plains killifish | *Fundulus zebribus* |
| Black bullhead | *Ictalurus melas* |
| Green sunfish | *Lepomis cyanellus* |
| Orangespotted sunfish | *Lepomis humilis* |
| **Documented by Hampton (1998) but not Previously Recorded** | |
| Western silvery minnow | *Hybognathus argyritis* |
| Emerald shiner | *Notropis atherinoides* |
| Goldeye | *Hiodon alosoides* |
| Red shiner | *Cyprinella lutrensis* |
| White bass | *Morone chrysops* |
| Freshwater drum | *Aplodinotus grunniens* |
| Smallmouth bass | *Micropterus dolomieu*i |
| Sauger | *Stizostedion canadense* |
| Spottail shiner | *Notropis hudsonius* |
| Plains topminnow | *Fundulus sciadicus* |
| Largemouth bass | *Micropterus salmoides* |
| Common carp | *Cyprinus carpio* |
| Creek chub | *Semotilus atromaculatus* |
| Yellow bullhead | *Ameiurus natalis* |
| Bluegill | *Lepomis macrochirus* |
| Northern pike | *Esox lucius* |

### Fish Health

The OST are concerned that fish are being affected by the Angostura Unit. Tribal members said they have seen fish in the river with lesions or open sores, and that populations may not be as abundant as they were in the past. In response, Reclamation, in cooperation with the OST, SDGF&P, USGS, South Dakota State University, and the USFWS (U.S. Fish and Wildlife Service), collected 101 fish from three sites in the river in August 1997, September 1998, and November 1998. The three sites were ¾-mile below the dam, at Oral, and at Red Shirt/Fairburn. Species collected were: Channel catfish, goldeye, white sucker, and shorthead redhorse. The samples were sorted and packaged in the field and sent frozen to NLS (Northern Lake Services) Crandon, Wisconsin, for tissue analysis.

This reduced-scale sampling was a follow-up to the NIWQP sampling and analysis done in 1988 (Greene et al. 1990), and was meant to supplement the NIWQP's 1994 Verification Study. Samples were analyzed for eight trace elements and a variety of organic contaminants, including herbicides, insecticides, and several PCB (polychlorinated biphenyl) isomers. The NLS results were then compared to the NIWQP study. The 85-percentile of the USFWS' NCBP (National Contaminants Bio-monitoring Program) provided the baseline, as shown in Table 3.25. Tissue of a total of 67 fish were sampled for heavy metals including aluminum,

**Table 3.25 Baseline for Fish Tissue Analysis**
(mg/kg wet weight [milligrams/kilogram])

| | NCBP Geometric Mean[1] | NCBP 85th percentile | NCBP 85th percentile | Other Levels | |
|---|---|---|---|---|---|
| | | 1990[1] | 1985[2] | Level Used | Source |
| Aluminum | | | | 100[3] | 4-100 (Animals in general) |
| Arsenic | 0.16 | 0.24 | 0.23 | | |
| Beryllium | | | | 0.6[3] | .05-.6 (Animals in general) |
| Copper | 0.72 | 1.00 | 1.02 | | |
| Mercury | 0.11 | 0.17 | 0.18 | | |
| Selenium | 0.45 | 0.71 | 0.18 | | |
| Thallium | | | | 0.10[3]<br>0.19[4] | (Animals in general; Fish in Minimata Bay[5]) |
| Zinc | 22.3 | 40.2 | 43.23 | | |

[1] Schmitt and Brumbaugh 1990. Average of samples collected in 1978-1979, 1980-1981, and 1984.
[2] Lowe, et al. 1985. Used in the NIWQP report; average of 1978-1979 and 1980-1981 samples.
[3] Pais and Jones 1997.
[4] Smith and Carson, 1977.
[5] Contaminated site in Japan.

arsenic, beryllium, copper, mercury, selenium, thallium, and zinc.

At the Oral site, samples were above baseline concentrations for copper, selenium, and zinc. Selenium was most frequently observed above its baseline concentration (over 80 %). Copper and zinc were above the baseline in over 50% of the samples. The frequency of exceeding the background at the Red Shirt site for each of the trace elements exceeding baseline at Oral was much lower. Only half the percentage of copper and selenium samples at Red Shirt exceeded the baseline in comparison to the Oral site, while no zinc samples were greater than baseline at the Red Shirt site. Trace element concentrations were higher above the District than below.

The NLS noted the samples were contaminated with zinc during preparation. The absence of

**Table 3.26: Contaminant Concentrations in Fish**
(in mg/kg)

| | EPA Fish Advisory Screening Value | Below Dam 1998 | At Oral 1997 | Fairburn/Red Shirt 1998 | Fairburn/Red Shirt 1997 |
|---|---|---|---|---|---|
| Aluminum | none | | 21.055 | | 11.834 |
| Arsenic | 1.35 | <0.25 | <0.26 | <0.25 | <0.27 |
| Beryllium | none | | <0.034 | | <0.039 |
| Copper | none | 1.916 | 1.163 | 1.145 | 1.014 |
| Mercury | 0.45 | <0.075 | <0.024 | <0.075 | <0.023 |
| Selenium | 22.5 | <0.720 | <1.030 | <0.387 | <0.678 |
| Thallium | none | | <0.44 | | <0.43 |
| Zinc | none | 11.039 | 22.73 | 11.72 | 18.54 |

Source: EPA 1999.

results greater than the baseline at Red Shirt site indicate zinc contamination did not significantly affect the samples at the downstream site.

Analytical recovery of mercury spikes in 1998 by NLS was low, ranging from 44-65%. Only 3 of 67 samples had measurable mercury, and all of these were less than 0.1 mg/Kg (milligram/kilogram), the reporting limit. NLS in 1999, however, improved recovery to more than 90%.

Significant differences in trace element concentrations were found among the fish species sampled. White suckers were significantly higher in aluminum, copper, and selenium than the goldeyes or channel catfish, while channel catfish were significantly lower in zinc than the other species.

Channel catfish showed a significant decrease in concentrations of aluminum, selenium, and zinc, and a significant increase in the copper concentration between the 1988 and 1997 samples. Goldeyes showed only a significant decrease in zinc. Changes in aluminum, copper, and selenium may be specific to a particular species, but the decrease in zinc was shown for all species and thus could be true of river fish in general.

A total of 34 fish were sampled for organic chemicals by Greene et al. (1990). The analytes included 20 insecticides, 14 herbicides, and 7 PCB's. Of these, 7 insecticides and 1 herbicide were found in measurable concentrations in the fish (no PCB's were found). Six of the seven insecticides are now banned, so these apparently represent residue from past use. All were persistent organochlorines. The remaining insecticide, *methoxychlor*, is not known to be used on District lands. The herbicide observed in fish samples, *alachlor*, is used in the District, but the tissue residue is lower downstream of the District than upstream. Fish exhibited lower tissue residues of organochlorines than has been shown in a